

A218 700

DTIC FILE COPY

2

AFWAL-TR-89-2011, Volume II

DEVELOPMENT OF HIGH-ACTIVITY
PARA- TO ORTHO-HYDROGEN
CONVERSION CATALYSTS
VOLUME II

DTIC
ELECTE
MAR 2 1990
S DCS D



Prepared by

James F. White
Air Products and Chemicals, Inc.
Allentown, PA 18195

28 September 1989

Final Report for Period August 1987 - October 1988.

Approved for public release; distribution is unlimited.

AERO PROPULSION AND POWER LABORATORY
WRIGHT RESEARCH AND DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6563

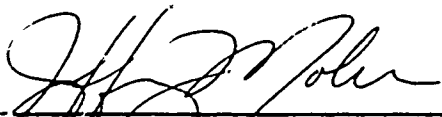
90 03 01 047

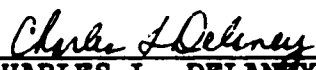
NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility or any obligation whatsoever. The fact that the Government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise in any manner construed, as licensing the holder, or any other person or corporation; or as conveying any rights or permission to manufacture, use, or sell as patented invention that may in any way be related thereto.

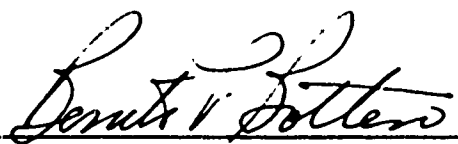
This report is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.


JEFFREY L. MOLER, 1Lt, USAF
Project Engineer
Fuels Branch


CHARLES L. DELANEY, Chief
Fuels Branch
Fuels and Lubrication Division

FOR THE COMMANDER


BENITO P. BOTTERI, Chief
Fuels and Lubrication Division
Aero Propulsion and Power Laboratory

If your address has changed, if you wish to be removed from our mailing list, or if the addressee is no longer employed by your organization, please notify WRDC/POSE WPAFB OH 45433-6563 to help us maintain a current mailing list.

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS None		
2a. SECURITY CLASSIFICATION AUTHORITY None			3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for Public Release; Distribution Unlimited.		
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE None					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) None			5. MONITORING ORGANIZATION REPORT NUMBER(S) AFWAL-TR-83-2011, Vol II		
6a. NAME OF PERFORMING ORGANIZATION Air Products & Chemicals, Inc		6b. OFFICE SYMBOL (if applicable)		7a. NAME OF MONITORING ORGANIZATION Wright Research & Development Center	
6c. ADDRESS (City, State, and ZIP Code) Allentown PA 18195			7b. ADDRESS (City, State, and ZIP Code) Wright-Patterson AFB OH 45433-6563		
8a. NAME OF FUNDING/SPONSORING ORGANIZATION WRIGHT RESEARCH AND DEVELOPMENT CENTER - APPL		8b. OFFICE SYMBOL (if applicable) WRDC/POSF		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F33615-87-C-2740	
8c. ADDRESS (City, State, and ZIP Code) Wright-Patterson AFB OH 45433-6563			10. SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT NO. 62203F	PROJECT NO. 3048	TASK NO. 05
			WORK UNIT ACCESSION NO. 67		
11. TITLE (Include Security Classification) Development of High-Activity Para- to Ortho-Hydrogen Conversion Catalysts. Volume II. (U)					
12. PERSONAL AUTHOR(S) White, James F.					
13a. TYPE OF REPORT Final		13b. TIME COVERED FROM 87Aug01 to 88Oct31		14. DATE OF REPORT (Year, Month, Day) 89 Sep 28	
15. PAGE COUNT 96					
16. SUPPLEMENTARY NOTATION Prepared under Air Products and Chemicals Project No. 87-7-1568					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP	Para-hydrogen to ortho-hydrogen conversion, Hydrogen conversion catalysis, Hypersonic vehicle engines, Hydrogen conversion catalysts, (K1) ←		
21	08	01			
21	09	01			
19. ABSTRACT (Continue on reverse if necessary and identify by block number) Literature search results for para- to ortho-hydrogen conversion catalysis: Bibliography; 1910 to present by year of publication. Keywords: Liquid propellant Rocket Engines; Liquid Rocket propellants; Bibliographies;					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS				21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a. NAME OF RESPONSIBLE INDIVIDUAL JEFFREY L. MOLER, 1Lt. USAF, Project Engineer				22b. TELEPHONE (Include Area Code) (513) 255-3549	
				22c. OFFICE SYMBOL WRDC/POSF	

DD Form 1473, JUN 86

Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

FOREWORD

This work was prepared by Air Products and Chemicals, Inc. and describes the work performed under Contract No. F33615-87-C-2740 during the period August 1987 through October 1988. The work was administered under the direction of the Aeronautical Systems Division, Aero Propulsion and Power Laboratory, Wright Research and Development Center (WRDC), Wright-Patterson Air Force Base (WPAFB), Ohio. Jeffrey Moler, 1Lt (WRDC/POSF) was the Air Force Project Engineer.

Mr. David Nahmias served as Air Products' Program Manager.

Two interim oral progress reports were presented to the Air Force on the Task 1 and Task 2 efforts on January 21, 1988 and July 21, 1988, respectively. In this written final report of the contract, the results from Task 3 as well as those from Tasks 1 and 2 are reported.

Accession For	
NTIS	CRA&I <input checked="checked" type="checkbox"/>
DTIC	IAS <input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution /	
Availability Codes	
Dist	Approved for Special
A-1	



ACKNOWLEDGMENT

Appreciation is extended to:

- Mr. James M. Nonnemaker for performing essentially all of the catalyst testing and much of the catalyst preparation.
- Mr. J. Douglas Moyer, Mr. Gerard Kuebler, and Dr. Eugene Karwacki for obtaining the catalyst characterization data.
- 1Lt Jeffrey Moler for assistance and advice when needed.
- Mr. Donald C. Amoss for writing the computer program which enabled quick and easy calculation of test results.
- Mr. Glenn Kinard and Dr. John L. Lewnard for helpful technical discussions and assistance with some of the calculations.
- Dr. Robert N. Miller for encouragement during the research program and assistance in publishing this report.
- Mr. Daniel W. Tyndall for timely reporting of contract spending and also for helping to publish this report.
- Ms. Marianne T. Phillips and Ms. Ann C. Gardner for helping to publish this report.
- Ms. Scarlet D. Erdosy and Ms. Susan J. Spadt for providing typing/word processing services.

APPENDIX E

Literature Search Results: Para/Ortho Hydrogen
Bibliography; 1910 to Present by Year of Publication

- Balandin, A. A., and Zelinsky, N. D., Z. physik. Chem. 126, 267 (1927).
- Benton, A. F., and Emmett, P. H., J. Am. Chem. Soc. 47, 346 (1925).
- Benton, A. F. and Elgin, J. C., J. Am. Chem. Soc. 48, 3027, (1926).
- Benton, A. F., and Elgin, J. C., J. Am. Chem. Soc. 49, 2426 (1927).
- Bonhoeffer, K. F., Z. physik. Chem. 113, 199 (1924).
- Chapman, D. L., Ramsbottom, J. E., and Trotman, C. G., Proc. Roy. Soc. London, A107, 92 (1925).
- Constable, F. H., Proc. Roy. Soc. London A108, 355 (1925).
- Dennison, D. M., Proc. Roy. Soc. Ser. A (London), 115, 483 (1927).
- Dennison, D. M. Proc. Roy. Soc., A113, p. 483 (1927).
- Dennison, D. M., Proc. Roy. Soc. Ser. A (London), 115, 483 (1927).
- Symmetrical and Antisymmetrical hydrogen and the third law of thermodynamics.
Thermal equilibrium and the triple-point pressure. Giauque, W. F. and
 Johnston H. L. J. Am. Chem. Soc. 50, 3221-8 (1928) C. A. 23, 7455.
- Heisenberg, W., Zeit. f. Physik, 41, p. 239 (1927).
- Heisenberg, W., Z. Physik, 41, 239 (1927).
- Heisenberg, W., Z. Physik, 41, 239 (1927).
- Hughes, D. R., and Bevan, D. C., Proc. Roy. Soc. London A117, 100 (1927).
- Hund, F., Zeit. f. Physik, 42, p. 93 (1927).
- Hund, F., Z. Physik, 42, 93 (1927).
- Hund, F., Z. Physik, 42, 93 (1927).
- Kistiakowsky, G. B., J. Phys. Chem. 30, 1356 (1926).
- Langmuir, I., J. Am. Chem. Soc. 35, 931 (1913); Z. anorg. Chem. 83, 261 (1914).
- Langmuir, I., J. Am. Chem. Soc. 34, 1310 (1912); ibid. 37, 417 (1915).
- Langmuir, I., Phys. Rev. 22, 374 (1923).
- Palmer, W. G., and Constable, F. H., Proc. Roy. Soc. London A107, 255 (1925).
- Taylor, H. S., Proc. Roy. Soc. London A108, 105 (1925).
- Taylor, H. S., and Kistiakowsky, G. B., Z. physik. Chem. 125, 341 (1927).
- Wolfenden, J. H., Proc. Roy. Soc. London A110, 464 (1925).

Para- and ortho-hydrogen, Barmois, E., La Nature No. 2820, 400-1 (1929) C.A. 24, 1020^b.

K. F. Bonhoeffer and P. Harteck, Z. Physik. Chem. Abt. B, 4, 113 (1929).

Bonhoeffer, K. F., and P. Harteck, Naturwiss. 17, p. 182 (1929).

Bonhoeffer, K. F., Harteck, P., Z. Physik. Chem., 84, 113 (1929).

Bonhoeffer, K. F., Harteck, P., Naturwiss., 17, 182 (1929).

Experiments on para- and ortho-hydrogen, Bonhoeffer, K. F. and Harteck, P. Sitzb. preuss. Akad. Wiss. 103-8 (1929) C.A. 23, 3382^b.

Experiments on para- and ortho-hydrogen, Bonhoeffer, K. F. and Harteck, P. Naturwissenschaften 17, 182 (1929) C.A. 23, 2614².

Para- and ortho-hydrogen, Bonhoeffer, K. F. and Harteck, P. Z. physik. Chem. Abt. B, 5 (1929) C.A. 24, 279⁸.

The specific heats of para-hydrogen in solid, liquid and gaseous states, Clusius, K. and Hiller K. Z. Physik. Chem. Abt. B 4 158-68 (1929) C.A. 23, 5071⁷.

Calorimetric determination of the energy differences in both hydrogen and modifications, Elbe, G. and Simon, F. Z. Physik. Chem. Abt. B, 6, 79-87 (1929) C.A. 24, 1573².

Change of the antisymmetric hydrogen molecule into the symmetric one. Eucken, A., Naturwissenschaften 17, 182 (1929), C.A. 23, 2613⁹.

The detection of the transformation of ortho-hydrogen into para-hydrogen by measurement of the specific heat, Eucken, A. and Hiller, K. Z. physik. Chem. Abt. B, 4, 142-57 (1929) C.A. 23 5071⁶.

Germer, L. H., Z. Physik 54, 408 (1929).

Hall, W. K., and Chapman, D. L., Proc. Roy. Soc. London A 124, 478 (1929).

Langmuir, I., and Kingdon, K. H., Phys. Rev. 35, 129 (1929).

McLennan, J. C., McLeod, J. H., Nature, 123, 160 (1929).

McLennan, J. C. and J. H. McLeod, Nature, 123, p. 160 (1929).

McLennan, J. C., McLeod, J. H., Nature, 123, 160 (1929).

Polanyi, M., Z. Elektrochem. 35, 561 (1929).

Demonstration of the interconversion of the two modifications of hydrogen. Senftleben H. Z. Physik. Chem. Abt. B, 4 169-73 (1929) C.A. 23, 5071⁵.

Senftleben, H., Z. Physik. Chem., 84, 169 (1929).

Senftleben, H., Z. Physik. Chem., 84, 169 (1929).

1929 Cont'd

Balandin, A. A., Z. physik. Chem. 82, 293 (1929).

Bonhoeffer, K. F., Harteck, P., Naturwiss., 17, 182 (1929).

Bonhoeffer, K. F., Harteck, P., Z. Physik. Chem., 84, 113 (1929).

Bonhoeffer, K. F. and Harteck, P., Z. physik. Chem. 84, 122 (1929).

Para- and ortho-hydrogen Bonhoeffer, K. F. and Harteck, P. Z. physik. Chem.
Abt. 84 113-41 (1929) C. A. 23 4383²

Frankenburger, W., and Mayrhofer, K., Z. Elektrochem. 35, 590 (1929).

Rupp, E. Z., Elektrochem. 35, 686 (1929).

1930's

Recent Advances in Science; Physics, Bates, L.F. Science Progress 24, 381-9 (1930) C.A. 24, 2370⁹.

Para and Ortho Hydrogen, Darmois, E., Rev. Gen. Sci. 41, 263-9 (1930) C.A. 24, 4218⁹.

Simple gas reactions Eyring, H. and Polanyi, M. Z. physik. Chem. Abt. b. 12, 279-311 (1931) C.A. 25 3548⁹.

Farkas, A., Z. Physik. Chem., 810, 419 (1930).

Farkas, A., Z. Physik. Chem., 810, 419 (1930).

Kinetics of the thermal transformation of para-hydrogen Farkas, A.Z., Elektrochem. 36, 782-4 (1930) Also in Z. physik. Chem. Abt. 810, 419-33 (1930) C.A. 25, 32⁴.

Para-hydrogen transformation on tungsten and nickel Farkas, A.Z. physik. Chem. Abt. 814, 371-86 (1931) C.A. 26 377⁸.

The paramagnetic conversion of parahydrogen and orthodeuterium in the presence of nitric oxide. (The magnetic moment of the deuteron), Farkas, L. and Garbatski, U.J., Chem. Phys. 6, 260-3 (1938) C.A. 32, 4881⁶.

Action of atoms on molecular hydrogen Geib, K.H. and Harteck, F.Z. physik. Chem. Bodenstein-Festband 849-62 (1931) C.A. 26, 655⁸.

Giauque, W.F., J. Am. Chem. Soc. 52, 4816 (1930).

Symmetrical and antisymmetrical hydrogen, Johnston, H.L., J. Chem. Education 7, 2030-4 (1930) C.A. 24, 5227¹.

Two modifications of hydrogen, Khariton, Yu., Uspekhi Fiz. Nauk. 10, 95-110 (1930) C.A. 28, 1265⁴.

Quastel, J.H., Trans. Faraday Soc. 26, 853 (1930).

Taylor, H.S., J. Am. Chem. Soc., 53, 578 (1931).

Taylor, H.S., and Sherman, A., Trans. Faraday Soc. 28, 247 (1932).

1931

Bonhoeffer, K.F., Farkas, A., Ibid., B12, 231 (1931).

K. F. Bonhoeffer, and A. Farkas, Z. Physik Chem. Abt. B, 12, 231 (1931).

Bonhoeffer, K.F. Farkas, A., Ibid., B12, 231 (1931).

Bonhoeffer, K.F., and Farkas, A., Z. physik. Chem. B12, 231 (1931).

The para-hydrogen transformation on platinum: A relation between catalysis and accommodation Bonhoeffer, K.F. and Farkas, A.Z. physik. Chem. Abt. B12, 231-46 (1931) C.A. 25 3908⁶.

Coehn, A., and Jurgens, H., Z. Physik. 71, 179 (1931).

Eyring, H., and Polanyi, M., Z. physik. Chem. B12, 279 (1931).

Farkas, A., Z. physik. Chem. B14, 371 (1931).

Formation of para-hydrogen under pressure at low temperatures. Farkas, A. and Bonhoeffer, K.F., Z. physik. Chem. Bodenstein-Festband, 638-40 (1931) C.A. 26, 655⁶.

Gieb, K.H., Harteck, P., Z. Physik. Chem., Bodenstein-Festband, 849 (1931).

Gieb, K.H., Harteck, P., Z. Physik. Chem., Bodenstein-Festband, 849 (1931).

Mayrhofer, K., and Schwamberger, E., ibid. 37, 473 (1931).

H.S. Taylor, J. Amer. Chem. Soc., 53, 578 (1931)

Taylor, H.S., Sherman, A., J. Am. Chem. Soc., 53, 1614 (1931).

Taylor, H.S., J. Am. Chem. Soc. 53, 578 (1931); Chem. Rev. 9, 1 (1931); Trans. Faraday Soc. 28, 131 (1932)

Taylor, H.S., Sherman, A., J. Am. Chem. Soc., 53, 1614 (1931).

Taylor, H.S., J. Am. Chem. Soc., 53, 578 (1931).

The ortho-para-hydrogen conversion at surfaces Taylor, H.S. and Sherman, A., J. Am. Chem. Soc. 53, 1614-5 (1931) C.A. 25, 2641¹.

Bonhoeffer, K.F., Farkas, A., Trans. Faraday Soc., 28, 242, 561 (1932).

K. F. Bonhoeffer and A. Farkas, Trans. Faraday Soc., 28, 242, 561 (1932).

Adsorption and reflection processes in the interaction of hydrogen and metals, Bonhoeffer, K.F. and Farkas, A. Trans. Faraday Soc. 28, 242-7 (1932) C.A. 26, 3977⁸.

Conversion of para-hydrogen to ortho-hydrogen over iron synthetic-ammonia catalysts, Emmett, P.H. and Harkness, R.W., J. Am. Chem. Soc. 54, 403-4 (1932) C.A. 26, 1191³.

Eyring, H., and Sherman, A., J. Am. Chem. Soc. 54, 2661 (1932).

Frankenburger, W., and Hodler, A., Trans. Faraday Soc. 28, 229 (1932).

Equilibrium of para- and orthohydrogen, Harkness, R.W. and Dening, W.E., J. Am. Chem. Soc. 54, 2850-2 (1932) C.A. 26, 4534¹.

Lennard-Jones, J.E., Trans. Faraday Soc. 28, 333 (1932).

Velocity coefficient of interchange reactions, Pelzer, H. and Wigner, E., Z. physik. Chem. B15, 445-71 (1932) C.A. 26, 2638⁷.

Developments of the theory of chemical reactions, Polanyi, M. Naturwissenschaften 20, 289-96 (1932) C.A. 26, 4231².

Quantum mechanics of activated adsorption, Sherman, A. and Eyring, H., J. Am. Chem. Soc. 54, 2661-75 (1932) C.A. 26, 4746³.

Tamm, I., Physik. Z. Sowjetunion 1, 733 (1932).

Taylor, H.S., Sherman, A., Trans. Faraday Soc., 28, 247 (1932).

Activated adsorption of hydrogen and the hydrogen conversion, Taylor, H.S. and Sherman, A. Trans. Faraday Soc., 28, 247-53 (1932) C.A. 26, 3977⁶.

Wieland, H., The Mechanism of Oxidation. Yale University Press, New Haven, 1932.

Crossing of potential thresholds in chemical reactions, Wigner, E., Z. physik. Chem. B19, 203-16 (1932) C.A. 27, 221³.

Bonhoeffer, K.F., Farkas, A., and Rummel, K. W., *Z. physik. Chem.* **B21**, 225 (1933).

K. F. Bonhoeffer, A. Farkas, and K.W. Rummel, *Z. Physik. Chem. Abt. B*, **21**, 225 (1933).

Heterogeneous catalysis of the para-hydrogen conversion, Bonhoeffer, K.P., Farkas, A. and Rummel, K.W., *Z. physik. Chem.* **B21**, 225-34 (1933) *C.A.* **27**, 3875⁴.

The para-ortho conversion of hydrogen, Burshtein, R. Kh. *Uspekhi Khim.* **2**, 691-9 (1933) *C.A.* **28**, 2269⁴.

From the physics of the atom to the physics of the molecule, Carbino, O.M., *Elettrotecnica* **20**, 118-21 (1933), *Science Abstracts* **36A**, 418 *C.A.* **27**, 5630⁴.

The conversion of ortho into para hydrogen in the solid state, Cremer, E., and Polanyi, M., *Z. physik. Chem.* **B21**, 459-68 (1933) *C.A.* **27**, 4148².

The catalytic interconversion of ortho-para-hydrogen over iron, platinum and nickel catalysts, Emmett, P.H. and Harkness, R.W., *J. Am. Chem. Soc.* **57**, 1624-31 (1935) *C.A.* **30**, 369².

Farkas, L., and Sachsse, H., *Z. Phys. Chem. Abt. B23*, 1, 19 (1933).

Farkas, A., and Farkas, L., *Nature* **132**, 894 (1933).

A. Farkas and L. Farkas, *Nature*, **132**, 894 (1933).

Farkas, L., Sachsse, H., *Z. Physik. Chem.* **B23**, 1, 19 (1933).

Farkas, L., and Sachsse, H., *Z. physik. Chem.* **B23**, 1, 19 (1933).

L. Farkas and H. Sachsse, *Z. Physik. Chem. Abt. B*, **23**, 1 (1933).

Homogeneous catalysis of the para-ortho-hydrogen conversion under the influence of paramagnetic molecules. I., Farkas, L. and Sachsse, H., *Z. physik. Chem.* **B23**, 1-18 (1933) *C.A.* **28**, 401⁶.

A micro method for determination of the concentration of ortho-para hydrogen mixtures, Farkas, A., *Z. physik. Chem. B* **22**, 344-9 (1933) *C.A.* **28** 37⁶.

Para and ortho hydrogen, Farkas, L. *Ergebnisse exakt. Naturw.* **12**, 163-218 (1933) *Science Abstracts* **36A**, 1326; cf. *C.A.* **27**, 3874-5. *C.A.* **28**, 3957⁹.

Franck, J., *Nachr. Ges. Wiss. Gottingen*, 293 (1933).

Harkness, R.W., and Emmett, P.H., *J. Am. Chem. Soc.* **55**, 3496 (1933); *ibid* **57**, 1624 (1935).

Conversion of ortho to para-hydrogen over iron catalysts at 190°, Harkness, R.W., *J. Am. Chem. Soc.* **57**, 1624-7 (1935) *C.A.* **27**, 4730⁷.

Iron promoted iron synthetic ammonia catalysts, Emmett, P.H., *J. Am. Chem. Soc.* **55**, 3496-7 (1933).

1933 Cont'd

Self-diffusion of hydrogen, Harteck, P. and Schmidt, H.W., Z. physik. Chem. B. 21, 447-58 (1933) C.A. 27, 4148.

Horiuti, J., and Polanyi, M., Nature 132, 819 (1933).

Relation between van der Waals' and activated adsorption on chromium oxide gel, Howard, John Nature 132, 603, (1933) C.A. 28, 949⁷.

Para Hydrogen, Josephy, E., Angew. Chem. 46, 256-8 (1933) C.A. 27, 3648¹.

Langmuir, I., Chem. Revs. 13, 147 (1933).

K.W. Rummel, Z. Physik. Chem. Abt. A, 167, 221 (1933).

Rummel, K.W., Z. Physik. Chem. A167, 221 (1933).

The para-hydrogen transformation on carbon surfaces at low temperatures, Rummel, K.W., Z. physik. Chem. A167, 221-39 (1933) C.A. 28, 2603⁸.

Taylor, J.B. and Langmuir, I., Phys. Rev. 44, 423 (1933).

H.S. Taylor and H. Diamond, J. Amer. Chem. Soc., 55, 2613 (1933).

Taylor, H.S., Diamond, H., Ibid., 55, 2613 (1933).

Taylor, H.S., and Diamond, H., J. Am. Chem. Soc. 55, 2613 (1933).

Taylor, H.S., Diamond, H., Ibid, 55, 2613 (1933).

Para-hydrogen conversion at paramagnetic surfaces, Taylor, H.S. and Diamond, H., J. Am. Chem. Soc. 55, 2613-14 (1933) C.A. 27, 3369⁵.

Theoretical and practical studies of atomic and molecular forms of the hydrogen isotopes, Taylor, H.S. and Eyring, H., Proc. Am. Phil. Soc., 72, 255-64 (1933) C.A. 28, 707².

E. P. Wigner, Z. Physik. Chem. Abt. B 23, 28 (1933).

E. Wigner, Z. Physik. Chem. Abt., B, 23, 28 (1933).

E. P. Wigner, Z. Physik. Chem. B23, 28 (1933).

Wigner, E., Z. Phys. Chem., Abt. B 23, 28 (1933).

Paramagnetic conversion of para-ortho hydrogen III, Wigner, E., Z. physik. Chem. B23, 28-32 (1933) C.A. 28, 401⁸.

de Boer, J.H., *Electron Emission and Adsorption Phenomena*. Cambridge University Press, London, 1935, p. 76.

Activated adsorption and para-ortho hydrogen conversion on charcoal. Burshtein, R. Kh. and Kashtanov, P. *Nature* 133, 571-2 (1934) C.A. 28, 3959⁹.

Activated adsorption of hydrogen on charcoal and its effect on the catalytic activity of charcoal, Burshtein, R. and Kashtanov, P., *Acta physicochim U.R.S.S.* 1, 465-72 (1934) (In German) C.A. 29, 6495⁴.

Cavanagh, B., Horiuti, J., and Polanyi, M., *Nature* 133, 797 (1934).

Farkas, A., Farkas, L., and Rideal, E.K., *Proc. Roy. Soc. London*, A146, 630 (1934).

A. Farkas and L. Farkas, *Proc. Roy. Soc. Ser. A*, 144, 16, 467 (1934).

Gould, A. J., Bleakney, W., Taylor, H.S., *J. Chem. Phys.*, 2, 362 (1934).

Horiuti, J., Ogden, G., and Polanyi, M., *Faraday Soc.* 30, 663 (1934).

Horiuti, J., and Polanyi, M., *Mem. Proc. Manchester Lit. & Phil. Soc.* 78, 47 (1934).

Horiuti, J., and Polanyi, M., *Trans. Faraday Soc.* 30, 1164 (1934).

The relation between activated and van der Waals adsorption, Howard, J., *Trans. Faraday Soc.* 30, 278-87 (1934) C.A. 28, 2589⁵.

The para-hydrogen conversion on glass. Magid, A.M. and Roginskii, S.Z., *J. Phys. Chem. U.R.S.S.* 5, 1278-82 (1934) C.A. 29, 5336².

E. W. Neuman, *J. Chem. Phys.*, 2, 31 (1934).

Roginsky, S., and Schechter, A., *Acta Physicochim. U.R.S.S.* 1, 318 (1934).

Function of adsorbed atoms in heterogeneous catalysis. Roginskii, S. *Acta Physicochim. U.R.S.S.* 1, 473-82 (1934) (In German) C.A. 29, 6494⁹.

The para-ortho-hydrogen conversion by the hydrogen iodide reaction and by iodine atoms, Rosenbaus, E.J. and Hogness, T.R., *J. Chem. Physics* 2, 267-72 (1934) C.A. 28, 4315³.

Para-ortho hydrogen conversion by catalysis on ions of the iron group. The dependence on concentration of magnetic moments of ions. Sachsse, H.Z. *physik. Chem.* B24, 429-36 (1934) C.A. 28, 3647⁷.

Scott, R.B., Brickwedde, F.G., Urey, H.C., Wahl, M.H., *J. Chem. Phys.*, 2, 454 (1934).

The vapor pressures and derived thermal properties of hydrogen and deuterium, Scott, Russell E., Brickwedde, Ferdinand G., Urey, H.C. and Wahl, N.K., *J. Chem. Physics* 2, 454 (1934) C.A. 28, 6605⁷.

Quantum theory of catalysis, Shukhovitzkii, A.A., *Acta Physicochim. U.R.S.S.* 1, 901-12 (1934) (In German) C.A. 29, 6494⁵.

de Boer, J.H., Electron Emission and Adsorption Phenomena. Cambridge University Press, London, 1935.

The conversion of ortho-para hydrogen under the influence of α -particles. Capron, F.C. Am. Soc. Sci. Bruxelles 558, 222-36 (1935) C.A. 30, 2841⁸.

Course of the reaction of the ortho-para-hydrogen conversion in solid hydrogen. Capron, P.C., Ann. Soc. Sci. Bruxelles, 558, 222 (1935).

Vapor pressure difference of the ortho and para modifications of the hydrogen isotope, Clusius, K. Z. physik. Chem. B 29, 159-61 (1935) C.A. 29, 7141⁹.

Cremer, E.Z. physik. Chem. 828, 199-214 (1935) C.A. 29, 3582⁴.

Kinetics of the heterogeneous ortho-para-hydrogen conversion on solid oxygen, Cremer, E.Z. physik. Chem. 828, 383-92 (1935) C.A. 29, 4660³.

Emmet, P.H., and Harkness, R.W., J. Am. Chem. Soc. 57, 1624 (1935).

Fajans, E., Z. Physik. Chem. 828, 239, 252, 1935.

Hydrogen catalysis on nickel, I. Comparison of the rate of conversion of para-hydrogen with the reaction rate $H_2 + O_2 \rightleftharpoons 2H_2O$ on nickel surfaces. Fajans, E.Z., physik. Chem. 828, 239-51 (1935) C.A. 29, 4251⁹.

A. Farkas, Orthohydrogen, Parahydrogen and Heavy Hydrogen, Cambridge University Press, London, 1935.

Kalckar, F., and Teller, E., Proc. Roy. Soc., Ser. A 150, 528 (1935).

Theory of the catalysis of the ortho-para transformation by paramagnetic gases. Kalckar, F. and Teller, E. Proc. Roy. Soc. (London) A150, 520-33 (1935) C.A. 29, 6826².

Leypunsky, O.I., Acta Physicochim. U.R.S.S. 2, 787 (1935).

Polanyi, M., J. Soc. Chem. Ind. 54, 123T (1935).

Roberts, J.K., Proc. Roy. Soc. London A152, 445 (1935).

E. Storfer, Z. Elektrochem., 41, 868 (1935).

Surhmann, R., and Csech, H., Z. physik. Chem. 828, 215 (1935).

The effect of heating a nickel catalyst on its ability to accelerate the conversion of para-hydrogen and the relation of the pyrochoric properties of nickel to the heating temperature, Tammann, G.Z. anorg. allgem. Chem. 224, 25-6 (1935) C.A. 29, 7774⁵.

Taylor, H.S., and Diamond, H., J. Am. Chem. Soc. 57, 1251 (1935).

H.B. Weiser, Inorganic Colloid Chemistry, John Wiley and Sons, New York (1935), p. 28.

Use of the ortho-para-hydrogen conversion in the detection of free radicals in photodissociation. West, W.J. Am. Chem. Soc. 57, 1931-4 (1935) C.A. 29, 7805⁴.

1936

R.W. Barrer, J. Chem. Soc., 1256 (1936).

R.M. Barrer, J. Chem. Soc., 1261 (1936).

Bryce, G., Proc. Cambridge Phil. Soc. 32, 648 (1936).

Kinetics of the para-ortho hydrogen conversion on charcoal, Burshtein, R. and Kashtenov, P. Trans. Faraday Soc. 32, 823-8 (1936) C.A. 30, 5105⁴.

Eley, D.O., and Polanyi, M., Trans. Faraday Soc. 32, 1388 (1936).

Catalytic interchange of hydrogen with water and alcohol, Eley, D.O. and Polanyi, M. Trans. Faraday Soc. 32, 1388-97 (1936) C.A. 31, 25⁹.

The theoretical treatment of chemical reactions produced by ionization processes. I. The ortho-para hydrogen conversion by α -particles. Eyring, H., Hirschfelder, J.O. and Taylor, H.S., J. Chem. Physics 4, 479-91 (1936). C.A. 30, 6648².

Farkas, A., Trans. Faraday Soc. 32, 416 (1936).

Farkas, A., Trans. Faraday Soc. 32, 922 (1936).

Farkas, A., Trans. Faraday Soc. 32, 929 (1936).

Morikawa, K., Benedict, W.S., and Taylor, H.S., J. Am. Chem. Soc. 58, 1445, 1795 (1936).

Okamoto, G., Horiuti, J., and Hirota, K., Sci. Papers Inst. Phys. Chem. Research (Tokyo) 29, 223 (1936).

Reynolds, P.W., and Chapman, D.L., Proc. Roy. Soc. London A 156, 284 (1936).

Roberts, J.K., Nature 137, 659 (1936).

Roberts, J.K., and Bryce, G., Proc. Cambridge Phil. Soc. 32, 653 (1936).

The para-ortho composition of hydrogen gas formed primarily from hydrogen atoms. Sasaki, N. and Mabuchi, O. Proc. Imp. Acad. (Tokyo) 12, 39-41 (1936) C.A. 30, 6285⁷.

Warburg, O., and Christian, W., Helv. Chim. Acta 19, E79 (1936).

- J. L. Bolland and H. W. Melville, Trans. Faraday Soc., 33, 1316 (1937).
- Bosworth, R.C.L., Proc. Cambridge Phil. Soc. 33, 394 (1937).
- Bosworth, R.C.L., and Rideal, E.K., Proc. Roy. Soc. London A162, 1 (1937).
- Bosworth, R.C.L., and Rideal, E.K., Physica 4, 925 (1937).
- P.H. Emmett and S. Brunauer, J. Am. Chem. Soc., Vol. 59, 1553 (1937).
- Farkas, A., and Farkas, L., Trans. Faraday Soc. 33, 678 (1937).
- Theory and experiment in exact science, Gerlach, W. Angew. Chem. 50, 10-18, (1937) C.A. 31, 2053⁹.
- Kuhn, R., and Strobele, R., Ber. 70B, 753 (1937).
- A comparison of the data of state of normal and para-hydrogen from the boiling point to 55°K. Long, E.A. and Brown, O.L.I., J. Am. Chem. Soc. 59, 1922-4 (1937) C.A. 31, 8285⁵.
- Morikawa, K., Trenner, N.R., and Taylor, H.S., J. Am. Chem. Soc. 59, 1103 (1937).
- Polanvi, M., Sci. J. Royal Coll. Sci. 7, 21 (1937).
- Molecular Volumes and Expansivities of liquid normal and para-hydrogen, Scott, Russell B. and Brickwedde, Ferdinand O. J. Research NBS 19, 237 (1937) C.A. 31, 7714⁹.
- Wang, J.S., Proc. Roy. Soc. London A161, 127 (1937).
- Warburg, O., Ergeb. Enzymforach. 7, 210 (1937).
- Compilation of thermal properties of hydrogen in its various isotopic and ortho-para modifications, Woolley, H.W., Scott, R.B., Brickwedde, F.G., NBS RP 1932; Nov. 1948.

1938

Brunauer, S., Emmett, P.H., Teller, E., J. Am. Chem. Soc., 60, 309 (1938).

Burstein, R., Acta Physicochim. U.R.S.S. 8, 857 (1938).

Salt effect in the paramagnetic conversion of parahydrogen, Calvin, M., J. Am. Chem. Soc. 60, 2003 (1938) C.A. 32, 7319⁴.

Evans, M.G., and Warhurst, E., Trans. Faraday Soc. 34, 514 (1938).

Johnson, R.P., Phys. Rev. 54, 459 (1938).

R. Juza, J. Langheim, and H. Hahn, Angew. Chem., 51, 354 (1938).

Michaelis, L., and Schubert, M.P., Chem. Revs. 22, 437 (1938).

Stearn, A.S. Ergeb. Enzymforsch. 7, 1 (1938).

E. Storfer, Trans. Faraday Soc., 34, 639 (1938).

Modern thermodynamics, Ubbelohde, A.R., Uspekhi Fiz. Nauk. 20; 281-316 (1938) C.A. 33, 4835⁹.

Van Cleave, A.B., Trans. Faraday Soc. 34, 1174 (1938).

Bosworth, R.C.L., Trans. Faraday Soc. 35, 397 (1939).

Conn, G.K.T., and Twigg, G.H., Proc. Roy. Soc. London, A171, 70 (1939).

Conversion of para-hydrogen in the presence of nitric oxide in aqueous solution (Collision number between solute molecules), Farkas, L. and Garbatski, U. Trans. Faraday Soc. 35, 263-8 (1939) C.A. 33, 3242^b.

Craxford, S.R., Trans. Faraday Soc. 35, 946 (1939).

Farkas, A., Trans. Faraday Soc. 35, 906 (1939).

Farkas, A., Trans. Faraday Soc. 35, 941 (1939).

Farkas, A., Trans. Faraday Soc. 35, 943 (1939).

Ortho-para conversion of hydrogen in diamagnetic liquids, Farkas, L. and Sandler, L., Trans. Faraday Soc. 35, 337-42 (1939) C.A. 33, 2795³.

Greenhalgh, R.K., and Polanyi, M., Trans. Faraday Soc. 35, 520 (1939).

Catalytic exchange of hydrogen, Horrex, C. and Greenhalgh, R.K. and Polanyi, M., Trans. Faraday Soc. 35, 511-20 (1939) C.A. 33, 4858⁸.

Lennard-Jones, J.E., and Coulson, C.A., Trans. Faraday Soc. 35, 811 (1939).

Morrison, J.L., and Roberts, J.K., Proc. Roy. Soc. London A173, 1, 13 (1939).

Pauling, L., The Nature of the Chemical Bond. Cornell University Press, Ithaca, 1939.

Pitkethly, R. C., and Steiner, H. S., Trans. Faraday Soc. 35, 979 (1939).

Pollard, W. G., Phys. Rev. 56, 324 (1939).

E. K. Rideal, Proc. Camb. Phil. Soc., 35, 130 (1939).

Roberts, J. K., Some Problems in Adsorption. Cambridge University Press, London, 1939.

Roberts, J. K., Trans. Faraday Soc. 35, 941 (1939).

Schechter, A., Acta Physicochim. U.R.S.S. 10, 379 (1939).

Parahydrogen conversion by biradicals, Georg Maria Schwab and Jurgen Voitlander, Naturwissenschaften 40, 439 (1939), C.A. 48, 7400 i.

Shockley, W., Phys. Rev. 56, 317 (1939).

Stephenson, M., Bacterial Metabolism. Longmans, Green, New York, 1939.

1939 Cont'd:

Taylor, H. S., and Turkevich, J., Trans. Faraday Soc. 35, 921 (1939).

Twigg, G. H. and Rideal, E. K., Proc. Roy. Soc. London, A171, 55 (1939).

Twigg, G. H., Trans. Faraday Soc. 35, 945 (1939).

Action of magnetized ferromagnetic catalyst, Ogawa, E. Tech. Rept. Kyushu Imp. Univ. 14, 243-61 (1939) C.A. 36, 4013^b.

Baxendale, J. H., and Warhurst, E., Trans. Faraday Soc. 36, 1181 (1940).

Beeck, O., Smith, A. E., and Wheeler, A., Proc. Roy. Soc. London A177, 62 (1940).

Kinetics of para-ortho hydrogen conversion on charcoal, Burshtein, R., Acta Physicochim U.R.S.S. 12, 201-8 (1940) (In English) C.A. 34, 7719⁸.

Conversion of para-hydrogen by porphyrin compounds including hemoglobin, Eley, D. D. Trans. Faraday Soc. 36, 500-5 (1940) C.A. 34, 4331².

Parahydrogen conversion on tungsten, Eley, D. D. and Rideal, E. K. Nature 146, (1940) C.A. 34, 7710⁷.

Estimation of semiquinone radicals by the conversion of para-hydrogen, Farkas, L. Ann. N. Y. Acad. Sci. 40, Art. 2, 129-32 (1940) C.A. 35, 2757¹.

L. Farkas and Y. L. Sandler, J. Chem. Phys., 8, 248 (1940).

Hinshelwood, C. N., Kinetics of Chemical Change. Oxford University Press, London, 1940.

Kinetic principles of the method of isotopic indicators. I. Kinetics of exchange reactions, Roginskij, S. Z. Bull. Acad. Sci. U.R.S.S. Classe sci. chim. (1940) 601-615 (In English 616) C.A. 35, 3150⁵.

The p-o conversion of hydrogen gas formed primarily from hydrogen atoms, II, Sasaki, N. and Mabuti, O., Proc. Imp. Acad. (Tokyo) 16, 223-4 (1940) (In German) C.A. 34, 7752³.

The para-ortho composition of ethyl alcohol photochemically yielding chiefly molecular hydrogen, Sasaki, N. and Mabuti, O., Proc. Imp. Acad. (Tokyo) 16, 401-2 (1940) C.A. 35, 6189⁶.

Radical character and para-hydrogen conversion, Schwab, G. M. and Schwas-Agallidis, E., Naturwissenschaften 28, 412-13 (1940) C.A. 35, 3148⁸.

Solid free radical as catalyst for ortho-para hydrogen conversion, Turkeyvich, J. and Selwood, P. W., J. Am. Chem. Soc. 63, 1077-9 (1941) C.A. 35, 3512⁷.

Twigg, G. H. and Rideal, E. K., Trans. Faraday Soc. 36, 533, 1940.

1941

The catalysis of the parahydrogen conversion by tungsten, Eley, D. A. and Rideal, E. K., Proc. Roy. Soc. (London) A178, 429-51 (1941) C.A. 36, 224.

Glasstone, S., Laidler, K. J., and Eyring, H., The Theory of Rate Processes. McGraw-Hill, New York, 1941.

Herington, E. F. G., Trans. Faraday Soc. 37, 361 (1941).

Miller, A. R. and Roberts, J. K., Proc. Cambridge Phil. Soc. 37, 82 (1941).

New binary (free) radicals, Muller, E. Angew. Chem. 54, 192-3 (1941) C.A. 35, 61663.

Roginsky, S. Z., J. Phys. Chem. U.R.S.S. 15, 1 (1941).

Turkevich, J., Selwood, P., Ibid., 63, 1077 (1941).

Turkevich, J., and Selwood, P. W., J. Am. Chem. Soc. 63, 1077 (1941).

Twigg, G. H., Proc. Roy. Soc. London A178, 106 (1941).

The mechanism of the catalytic conversion of para-hydrogen on nickel, platinum and palladium, Farkas, A. and Farkas, L., J. Am. Chem. Soc. 64, 1594-9 (1942) C.A. 36, 5141⁹.

Hogness, T. R., A Symposium on Respiratory Enzymes. University of Wisconsin Press, Madison, 1942.

Para-ortho composition of molecular hydrogen produced primarily from hydrogen atoms, Mabuchi, O., J. Chem. Soc. Japan 63, 574-81 (1942) C.A. 44, 10412 a.

Para and ortho constituents of hydrogen molecules which are photochemically produced primarily from ethyl alcohol, Mabuchi, O., J. Chem. Soc. Japan 63, 943-8 (1942) C. A. 41, 3372g.

Studies of catalytic action by conversion between parahydrogen and ortho-hydrogen. I. a. Conversion by magnetized nickel wire. b. Conversion by catalyst for ammonia synthesis, Ogawa, E. Toda, M. and Okumo, L., J. Soc. Chem. Ind., Japan 45, Suppl. binding, 387-9 (1942) (In English) C.A. 44, 7637a.

Schlenk, F., A Symposium on Respiratory Enzymes, University of Wisconsin Press, Madison, 1942.

1943

Heat, mass and momentum transfer in the flow of gases through granular solids. Gamson, B.; Thodos, G.; Hougen, O., Trans. Amer. Inst. Chem. Eng.; (43); 39, 1-35.

Hougen, O. A., Watson, K. M., Ind. Eng. Chem., 35, 529 (1943).

Huberman, N. D., and Rittenberg, D., J. Biol. Chem. 147, 211 (1943).

Rideal, E. K., Sabatier Lecture, Chemistry & Industry 62, 335 (1943).

The mechanism of catalytic hydrogenation, Rideal, E. K., Chemistry and Industry (1943), 335-8 C.A. 38, 158.

Yang, K. H., Hougen, O. A., Ind. Eng. Chem., 35, 529 (1943).

1944

Frankenburg, W. G., J. Am. Chem. Soc. 66, 1827, 1838 (1944).

Herington, E. F. G., and Rideal, E. K., Trans. Faraday Soc. 40, 505 (1944).

1945

Beeck, O., Rev. Modern Phys. 17, 61 (1945).

Herington, E. F. G., and Rideal, E. K., Proc. Roy. Soc. London A184, 434, 447 (1945).

Mass transfer in the flow of gases through granular solids extended to low modified Reynolds numbers.

Wilke, C. R.; Hougen, O. A.

Trans. Amer. Inst. Chem. Eng.; (45) 41; 445-451.

Davis, R. T., J. Am. Chem. Soc. 68, 1395 (1946).

Eley, D. O., Nature, 158, 449 (1946).

Glasstone, S., "Textbook of Physical Chemistry," 2nd ed., D. Van Nostrand Co., Inc., New York (1946).

Separation of ortho hydrogen and para hydrogen by thermo-diffusion in a separating tube, Schafer, K. and Corte, H., Naturwissenschaften 33, 92-3 (1946) C.A. 41, 7179 d.

Schwab, G. M., Trans. Faraday Soc. 42, 689 (1946).

A quantum-mechanical diffusion effect, Waldmann, L., Z. Naturforsch. 1, 483-4 (1946) C.A. 41, 5009 d.

1947

Balandin, A. A., Acta Physicochim. U.R.S.S. 22, 80 (1947).

Ortho hydrogen and para hydrogen at the triple points, Eruni, G., Chimica (Milan) 2, 87-90 (1947) C.A. 41, 7182 d.

Halsey, G., and Taylor, H. S., J. Chem. Phys. 15, 624 (1947).

Neutron scattering in ortho and para hydrogen, Hamermesh, M. and Schwinger, J., Phys. Rev. 71, 678-80 (1947) C.A. 41, 4705 h.

The para-ortho-hydrogen conversion by paramagnetic substances in solution.
Claeys, Y., Baes, C. F. Jr. and Wilmarth, W. K., J. Chem. Phys. **16**, 425-5.
(1948) C.A. **42**, 4429g.

Absolute rate of conversion of parahydrogen by metallic catalysts. Eley, D.
D., Trans. Faraday Soc. **44**, 216-26 (1948) C.A. **43**, 26g.

D. D. Eley, Advances in Catalysis, Vol. 1, (W. G. Frankenburg, V. I.
Komarewsky, and E. K. Rideal, eds.), Academic Press, New York, 1948, p. 157.

Eley, D. D., Advances in Catalysis **1**, 175 (1948).

Eley, D. D., Trans. Faraday Soc. **44**, 216 (1948).

Condensed-gas calorimetry. I. Heat capacities, latent heats, and entropies of
pure para-hydrogen from 12.7 to 20.3°. Description of the condensed-gas
calorimeter in use in the cryogenic laboratory of the Ohio State University,
Johnston, H. L., Clarke, J. T., Rifkin, E. B. and Kerr, E. C., J. Am. Chem.
Soc. **72**, 3933-8 (1950) C.A. **45**, 1861 h.

The rate of evaporation of liquid hydrogen due to the ortho-para hydrogen
conversion, Larsen, A. H., Simon, F. E. and Swenson, C. A., Rev. Sci.
Instruments **19**, 266-9 (1948) C.A. **42**, 4811 h.

Catalytic research on alloys, XII. The para-hydrogen conversion on Cu-Pt mixed
crystals, Rienacker, G. and Sarry, B., Z. anorg. Chem. **257**, 41-58 (1948) C.A.
43, 4088b.

R. H. Savage and C. Brown, J. Amer. Chem. Soc., **70**, 2362 (1948).

H. W. Wolley, R. B. Scott, and F. G. Brickwedde, J. Res. Nat. Bur. Stand., **41**,
379 (1948).

Compilation of thermal properties of hydrogen in its various isotopic and
ortho-para modifications.

1949

Theory of Homogeneous spontaneous ortho-para transitions in hydrogen at low temperatures, Abrikosov, A. A., Zhur. Eksptl. Teoret. Fiz. 19, 851-3 (1949) C.A. 45, 10014 a.

Parahydrogen catalysis by transition metals, Couper, A. and Eley, D. D., Nature 164, 578-9 (1949) C.A. 44, 2355a.

Diffusion, fluid flow, and reaction velocity in the interior of porous catalyst bodies, Wicke, E. and Bretz, H. Chemie-Ing.-Tech. 21, 219-28 (1949) C.A. 43, 7313i.

The parahydrogen conversion on palladium-gold alloys, Couper, A. and Eley, D. D., Discussions Faraday Soc. (1950) No. 8, 172-9 discussion 179-84, C.A. 45, 9988a.

The mechanism and temperature coefficient of the para-hydrogen conversion, Rideal, E. K. and Trapnell, B. M. W., Discussions Faraday Soc. (1950) No. 8, 114-18 C.A. 45, 9986 g.

The catalysis of the ortho-para conversion in liquid hydrogen, Swenson, J. Chem. Phys. 18, 520-2 (1950) C.A. 44, 9223e.

1951

Para-hydrogen conversion on tungsten, Halsey, G. D. Jr., Trans. Faraday Soc. 47, 649-56 (1951) C.A. 45, 9993e.

R. H. Savage, Ann. N.Y. Acad. Sci., 53, 862 (1951).

Viscosity difference between ortho and para hydrogen at low temperatures. E. W. Becker and O. Stehl. Z. Physik 133, 615-28 C.A. 47, 9699 i. (1952) cf. C.A. 46, 9366 d.

Electronic basis of catalyst activity. III. The reversible dissociation of hydrogen molecules and the para-hydrogen conversion, A. Couper and D. D. Eley, Proc. Roy. Soc. (London) A211, 536-43 (1952), C.A. 46, 10819 i. cf. C.A. 45, 9988 a.

A highly effective catalyst for the ortho-to-para hydrogen conversion. E. R. Grilly, U.S. Atomic Energy Comm. Natl. Sci. Foundation, Washington, D. C., AECU-2245, 4 pp. (1952); C.A. 48, 31e. cf. LADC-1136.

Ortho-para conversion of deuterium in molecular electric fields, Y. L. Sandler (Hebrew Univ., Jerusalem, Israel), J. Chem. Phys. 20, 1050 (1952); C.A. 46, 10709 i. cf. C.A. 33, 2795³.

Wilmarth, W. F. and Baes, C. F., Jr., J. Chem. Phys. 20, 116 (1952).

Liquefaction and storage of partially converted liquid hydrogen, E. R. Grilly, Rev. Sci. Instr. 24, 1-4 (1953), C.A. 47, 10906 g.

The catalysis of the para-hydrogen conversion by the solid free radical 2, 2-diphenyl-1-picrylhydrazyl, L. G. Harrison and C. A. McDowell, Proc. Roy. Soc. (London) A220, 77-90 (1953), C.A. 48, 4299a.

The effect of external magnetic field on the activity of ferromagnetic catalysts, E. Justi and G. Vieth, Z. Naturforsch. 8a, 538-46 (1953) C.A. 48, 4298 h.

Kinetics of surface reactions in the case of interactions between adsorbed molecules, Keith J. Laidler, J. Phys. Chem. 57, 318-19 (1953) C.A. 47, 6234 f.

Mechanisms of surface-catalyzed reactions. I. The para-hydrogen conversion on tungsten. Keith J. Laidler, J. Phys. Chem. 57, 320-7 (1953) C.A. 47, 6234 h.

Kinetic analysis of flow catalysis of ortho- to para-hydrogen. J. D. Rogers, Ind. Eng. Chem. 45, 1574-6 (1953), C.A. 47, 10325 f.

Kinetic analysis of flow catalysis of ortho- to para-hydrogen. A correction, J. D. Rogers, Ind. Eng. Chem. 45, 2576 (1953) C.A. 48, 4948 f. cf. C.A. 47, 10325 f.

The kinetics of the heterogeneous para-hydrogen conversion, Y. L. Sandler, J. Phys. Chem. 21, 2243-4 (1953) C.A. 48, 4296 a.

Veith, G., Z. Naturforschung., 8A, 538 (1953).

Conversion of ortho-para hydrogen by cuprous acetate in quinoline. W. K. Wilmarth and Max K. Barsh (Univ. of S. California, Los Angeles). J. Am. Chem. Soc. 75, 2237-42 (1953). C.A. 47, 9124 h.

The catalytic conversion of parahydrogen by paramagnetic complex ions in aqueous solution, W. K. Wilmarth and C. F. Baes, Jr., J. Chem. Phys. 20, 116-21 (1952) C.A. 46, 6475 c. cf. Cayleys, et. al., C.A. 42, 4429 g.

Barrick, P. L., Weitzel, D. W., Connolly, T. W., Proc. Cryog. Eng. Conf., 1, 285 (1954).

Fractionating converter for producing parahydrogen. W. F. Giaque, Rev. Sci. Instr. 25, 886-7 (1954) C.A. 49, 8633 e.

W. B. Innes, in Catalysis, Vol. 1, P. H. Emmett (ed.), Reinhold, New York (1954), p. 272.

Thermal conductivities of condensed gases. I. The thermal conductivity of liquid nitrogen between 65 and 90°K. Robert W. Powers, Robert W. Mattox, and Herrick L. Johnston. J. Am. Chem. Soc. 76, 5968-73 (1954) C.A. 49, 3597 e.

The ortho-para conversion of hydrogen and deuterium on inhomogeneous paramagnetic surfaces. Y. L. Sandler, Can. J. Chem. 32, 249-60 (1954), C.A. 48, 11858 b. cf. C.A. 48, 4296a.

Parahydrogen conversion by metal compounds of cyclopentadiene and indene. G. M. Schwab, E. O. Fischer, and J. Voitlander. Naturwissenschaften 41, 228 (1954), C.A. 49, 3590 a.

Condensed-gas calorimetry. VI. The heat capacity of liquid parahydrogen from the boiling point to the critical point. A. Lee Smith, Nathan C. Hallett, and Herrick L. Johnston, J. Am. Chem. Soc. 76, 1486-8 (1954) C.A. 48, 6804 d. cf. C.A. 48, 1792 b.

Conversion of ortho- to para-hydrogen in the liquid phase. G. L. Squires and A. T. Stewart, J. Chem. Phys. 22, 754 (1954) C.A. 48, 9135 g. cf. C.A. 47, 9894 d.

Barrick, P. L., Weitzel, D. W., Connolly, T. W., Proc. Cryog. Eng. Conf., 1, 285 (1954).

A thermal separation of ortho- and para-hydrogen at low temperatures. E. W. Becker, H. Henkes, and U. Seifert. Z. physik. Chem. (Frankfurt) [N. F.] 5, 90-9 (1955), C.A. 49, 14403 f.

The transport properties and the equation of state of gaseous para and ortho-hydrogen and their mixtures below 40°K. E. G. D. Cohen, M. J. Offerhaus, J. M. J. van Leeuwen, B. W. Roos, and J. de Boer. Physica 21, 737-9 (1955) (in English), C.A. 50, 9808 a.

Corrigan, T. E., Chem. Eng., 65, 200 (1955).

Hydrogen-activating enzymes of bacteria. A. Couper, D. D. Eley, and A. Hayward. Discussions Faraday Soc. No. 20, 174-84 (1955) (Pub. 1956) C.A. 50, 14866 h.

The catalysis of the para-hydrogen conversion by zinc oxide. L. G. Harrison and C. A. McDowell. Proc. Roy. Soc. (London) A228, 66-82 (1955) C.A. 49, 7947 b.

Parahydrogen conversion in solution. I. parahydrogen conversion by metallorganic compounds. G. M. Schwab and J. Voitlander. Z. physik. Chem. [N.F.] (Frankfurt) 3, 341-54 (1955), C.A. 49, 7435 e.

Nuclear spin-lattice relaxation in solid hydrogen. Tadashi Sugawara, Phys. Rev. 100, 759 (1955). C. A. 50, 3078 d. cf. C.A. 49, 12955 h.

Trapnell, B. M. W., "chemisorption", p. 10, Butterworths, London, 1955.

Catalysis: Hydrogenation and Dehydrogenation. Paul H. Emmett, Reinhold Publishing Corp., New York, N. Y. Vol. 3, 504 pp. (1955). Parahydrogen and orthodeuterium conversions and the hydrogen-deuterium exchange. B. M. W. Trapnell, Pages 1-48-101 references C.A. 49, 12753 a.

The magnetocatalytic effect of the ortho-para hydrogen conversion of nickel catalysts. Gerhard Vieth, Z. Naturforsch, 10a, 330-9 (1955) C.A. 51, 4116 i.

Kinetic studies with parahydrogen. G. Boocock and H. O. Pritchard. J. Phys. Chem. 60, 1329-31 (1956). C.A. 51, 3247 g.

Analysis of mixtures of ortho- and para-hydrogen and the catalytic conversion orthohydrogen == parahydrogen. Mme. F. Botter and G. Dirian. Comm. energie atomique (France), Rappt. No. 589, 25 pp. (1956). C. A. 51, 16201 e.

Theory of the transport properties of para-ortho mixtures in the gas phase. E. G. D. Cohen and M. J. Offerhaus. Proc. Intern. Symposium Transport Process. Statist. Mech. Brussels 1956, 169-72 (Pub. 1958) C.A. 53, 13711 d.

The transport properties and the equation of state of gaseous para- and ortho-hydrogen and their mixtures below 40°K. E. G. D. Cohen, M. J. Offerhaus, J. M. J. van Leeuwen, B. W. Roos, and J. de Boer. Physica 22, 791-815 (1956) C.A. 52, 10672 f. cf. C.A. 50, 9808 a.

Heat conduction in solid hydrogen. R. W. Hill and B. Schneidmesser. Bull. inst. intern. froid, Annexe 1956-2, 115-17. C.A. 52, 861 i.

Theory of the ortho-para conversion in solid hydrogen. Kazuko Mochizuki and Takeo Nagamiya. J. Phys. Soc. Japan 11, 93-104 (1956) C.A. 50, 9121 c.

Effect of self-diffusion on the ortho-para conversion in oxygen contaminated solid hydrogen. Kazuko Motizuki and Takeo Nagamiya. J. Phys. Soc. Japan 11, 654-6 (1956). C.A. 51, 31 i. cf. C.A. 50, 9121 d.

Catalytic investigation of alloys. XVI. The parahydrogen conversion on copper-palladium alloys. G. Rienacker and G. Vormum. Z. anorg. u. allgem. Chem. 283, 287-98 (1956). C.A. 50, 11789 g cf. C.A. 48, 6049 i.

Behavior of dicyclopentadienyl and diindenyl metal complexes toward the para-hydrogen conversion. Reply to the paper: "Parahydrogen conversion in solution" by G. M. Schwab and J. Voitlander. Ernst Ruch. Z. Physik. Chem. (Frankfurt) N.F. 6, 356-70 (1956). C.A. 50, 7551 g. cf. S. and V., C.A. 49, 7435 e. Reply to the remark by E. Ruch. Jurgen Voitlander (Univ. Munich, Ger.). Ibid. 371-5.

Selwood, P. W., "Magnetochemistry," p. 157. Wiley (Interscience), New York, 1956.

Selwood, P. W., J. Am. Chem. Soc. 78, 3893 (1956).

W. R. Smith and M. H. Polley, J. Phys. Chem., 60, 689 (1956).

Weitzel, D. H., Draper, J. W., et al., Advances in Cryogenic Engineering, Vol. 2, 12-18 (1956).

Weitzel, D. H., Proc. Cryog. Eng. Conf., 2, 12 (1956).

Iron catalyst for production of liquid parahydrogen. D. H. Weitzel and O. E. Park., Rev. Sci. Instr. 27, 57-8 (1956). C.A. 51, 7821 c. cf. Giauque, C.A. 49, 8633 e.

The surface catalysis of the ortho- to para-conversion in hydrogen under pressure at low temperatures. Douglas S. Chapin and Herrick L. Johnston, J. Am. Chem. Soc. 79, 2406-12 (1957). C.A. 51, 12623 f.

Efficient utilization of ortho-para (hydrogen conversion) catalyst. C. R. Class, R. P. Spero, and G. E. McIntosh. Proc. Cryogenic Eng. Conf., 2nd, Boulder 1957, 64-72. C. A. 52, 14302 f.

Parahydrogen conversion on copper, silver, and gold. D. D. Eley and D. R. Rossington. Chemisorption, Proc. Symposium, Keele 1956 137-51 (Pub. 1957). C.A. 52, 8706 d.

Nonideality of liquid ortho-parahydrogen solutions. Harold L. Friedman. J. Chem. Phys. 27, 220-3 (1957) C.A. 51, 17300 i.

Heat capacity of solid deuterium between 0.3 and 13°K. O. D. Gonzalez, David White, and H. L. Johnston. J. Phys. Chem. 61, 773-80 (1957) C.A. 51, 14402 c.

P. Handler, Semiconductor Surface Physics, Univ. of Pennsylvania Press, Philadelphia, 1957, p. 23.

Theory of the para-ortho transformation in solid deuterium. Kazuko Mochizuki, J. Phys. Soc. Japan 12, 163-60 (1957). C.A. 54, 8181 d.

R. E. Schlier and H. E. Farnsworth, Semiconductor Surface Physics, Univ. of Pennsylvania Press, Philadelphia, 1957, p. 13.

Parahydrogen conversion on manganese dicyclopentadienyl at room temperature and at -77°. G. M. Schwab, J. Voitlander, and A. Baumel. Z. Physik. Chem. (Frankfurt) 10, 343-6 (1957) C.A. 51, 11022 a. cf. C.A. 49, 7435 e.

The parahydrogen conversion by biradicals. G. M. Schwab and A. Baumel. Z. physik. Chem. (Frankfurt) 10, 347-9 (1957). C.A. 51, 11022 b. cf. C.A. 48, 7400 i.

Conversion of ortho- to para-hydrogen on iron oxide-zinc oxide catalysts. R. Eldo Svadlenak and Allen B. Scott. J. Am. Chem. Soc. 79, 5385-8 (1957) C.A. 52, 5947 d.

Catalysis of the ortho-parahydrogen conversion. D. H. Weitzel, J. W. Draper, O. E. Park, K. D. Timmerhaus and C. C. Van Valin. Proc. Cryogenic Eng. Conf. 2nd, Boulder, 1956, 12-18 (Pub. 1957). C.A. 52, 17923 e.

Reactions of parahydrogen and of deuterium with glass surfaces. G. S. Annis, H. Clough, and D. D. Eley. Trans. Faraday Soc. 54, 194-9 (1958). C.A. 52, 17860 d.

D. E. G. Austen, D. J. E. Ingram, and J. G. Tapley, Trans. Faraday Soc., 54, 400 (1958).

CHEMABS patent 61002759s, Production and storage of converted hydrogen, Vander Avend P.C., Air Products and Chemicals, Inc., Pat. No. US 3,094,390, Date 9/07/58.

Symmetry effects in gas kinetics. II. Ortho- and para-hydrogen. R. A. Buckingham, A. R. Davies, and D. C. Gilles (Univ. Coll., London), Proc. Phys. Soc. (London) 71, 457-69 (1958); cf. C.A. 49, 12092i. C.A. 54, 20386e.

Symmetry effects in the kinetic theory of gaseous para-ortho mixtures. E. G. D. Cohen and M. J. Offerhaus. Physica. 24, 742-50 (1958) (In English) C.A. 53.

The parahydrogen conversion on metals. A. Couper, D. D. Eley, M. J. Hulatt, and D. R. Rossington. Bull. Soc. chim. Belges 67, 343-57 (1958) (in English). C.A. 53, 5843 e.

Surface catalysis of the ortho to para conversion in liquid hydrogen by paramagnetic oxides on alumina. Clarence M. Cunningham and Herrick L. Johnson. J. Am. Chem. Soc. 80, 2377-82 (1958). C.A. 52, 16851 b:

Cunningham, C. M. and Johnston, H. L., J. Am. Chem. Soc. 80, 3277 (1958).

Separation of orthohydrogen from parahydrogen, and of paradeuterium from ortho-deuterium by preferential adsorption. Clarence M. Cunningham, Douglas S. Chapin, and Herrick L. Johnston, J. Am. Chem. Soc. 80, 2382-4 (1958) C.A. 52, 16851 d. cf. C.A. 52, 16851 a.

H. E. Farnsworth, R. E. Schlier, J. H. George, and R. M. Burger, J. Appl. Phys., 29, 1150 (1958).

Keeler, R. N., Timmerhaus, K. D., Proc. Cryog. Eng. Conf., 4, 296 (1958).

The effect of oxygen molecules contained in solid hydrogen on the rate of ortho-para conversion. Kazuko Mochizuki and Takeo Nagamiya (Univ. Osaka). J. Phys. Soc. Japan 14, 1639-40 (1959). C.A. 55, 21710h.

Separation of ortho-hydrogen and parahydrogen. Wm. R. Moore and Harold R. Ward. J. Am. Chem. Soc. 80, 2909-10 (1958) C.A. 52, 17893 g.

1958 Continued

Hindered rotation in adsorbed hydrogen. Adiabatic cooling by adsorbed para-hydrogen. Y. L. Sandler. J. Chem. Phys. 29, 97-9 (1958) C.A. 52, 17891 h.

J. Turkevich and J. Laroche, Z. Physik. Chem., 15, 399 (1958).

Weitzel, D. H., Blake, J. H. and Konecnik, M., Flow Conversion Kinetics of Ortho- and Para-Hydrogen. Advan. Cryog. Eng. 4, 286 (1958).

Weitzel, D. H., J. Res. Nat. Bur. Std. A., 60, 221 (1958).

Ortho-para catalysis in liquid-H production. D. H. Weitzel, W. V. Loebenstein, J. W. Draper, and O. E. Park, J. Research Natl. Bur. Standards 60, 221-7 (1958). C.A. 52, 16850 f. (Research paper 2840).

Weitzel, D. H., Ibid., 4, 286 (1958).

Weitzel, D. H., Loebenstein, W. V., Draper, J. W., and Park, O. E., J. Research Natl. Bur. Standards 60, 2840 (1958).

Statistical mechanics of solid and liquid mixtures of ortho- and parahydrogen. A. Bellmans and Agnessa Babloyantz. *Mol. Phys.* 2, 160-80 (1959). C.A. 53, 19502 h.

Surface catalysis of the ortho to para conversion in hydrogen under pressure at liquid-nitrogen temperature. Douglas S. Chapin (Ohio State Univ., Columbus). *Univ. Microfilms* (Ann Arbor, Mich.), L. C. Card No. Mic 59-2712, 102 pp.; *Dissertation Abstr.* 20, 488-90 (1959). C.A. 53, 21100 i.

Surface catalysis of the ortho-para conversion in liquid hydrogen by paramagnetic oxides on alumina. Clarence M. Cunningham (Ohio State Univ., Columbus). *Univ. Microfilms* (Ann Arbor, Mich.), L. C. Card No. Mic 59-2758, 89 pp.; *Dissertation Abstr.* 20, 1185-8 (1959), C.A. 54, 412 h.

Organic solids and heterogeneous catalysis. Electron transfer in 2,2-diphenyl-1-picrylhydrazyl. D. D. Eley and H. Inokuchi (Univ. Nottingham, Engl.). *Z. Elektrochem.* 63, 29-34 (1959) (In English). C.A. 53, 7741c.

Hindered-rotator model for adsorbed hydrogen at low temperatures. Arthur A. Evett (Univ. of Arizona, Tucson). *J. Chem. Phys.* 31, 565-6 (1959). C.A. 54, 2877e.

Z. D. Jastrzebski, Engineering Materials, J. Wiley and Sons, New York (1959), p. 351.

A new arrangement for the ortho-para conversion of liquid hydrogen in the large CEL-NBS Liquefier. V. J. Johnson. *Proc. Cryogenic Eng. Conf.*, 2nd, Boulder 1956, 19-26 (Pub. 1957). C.A. 52, 17923 h.

Thermodynamic properties of H₂ and D₂ at temperatures between 175° and 150° and at densities up to 840 amagats. A. Michels, W. DeGraaff, and G. J. Wolkers (Gemeente Univ., Amsterdam). *Physica* 25, 1097-1124 (1959) (In English). C.A. 54, 20453a.

Heat of adsorption of parahydrogen and orthodeuterium on Graphon. E. L. Pace and A. R. Siebert (Western Reserve Univ., Cleveland, O.). *J. Phys. Chem.* 63, 1398-1400 (1959) C.A. 54, G248h.

Surface properties of germanium. Y. L. Sandler and M. Gazith (Westinghouse Elec. Co., Pittsburg, Pa.), *J. Phys. Chem.* 63, 1095-1102 (1959). C.A. 54, 1051 c.

The magnetocatalytic effect. III. Georg M. Schwab and Anton Kaiser (Univ. Munich, Ger.) *Z. physik. Chem. (Frankfurt)* 22, 220-31 (1959); cf. C.A. 49, 10716 d. *Chem. Abst. Vol.* 54, 10480 a.

Scott, R. B., Cryogenic Engineering, D. Van Nostrand Co., Inc., Princeton (1959), p. 289.

1959 Continued:

Nickel, copper, and some of their alloys as catalysts for ortho-para hydrogen interconversion. Phoebe B. Shallicross and W. Walker Russell (Brown Univ., Providence, R.I.) J. Am. Chem. Soc. 81, 4132-7 (1959) C.A. 55, 14024 a.

Copper, nickel and some of their alloys as catalysts for ortho-para hydrogen interconversion. Phoebe B. Shallicross (Brown Univ., Providence, R.I.). Univ. Microfilms Dissertation Abstr. 19, 2245 (1959). C.A. 53, 10928 a.

Calculation of the rates of the ortho-para conversion and isotope exchanges in hydrogen. Isaiah Shavitt (Univ. of Wisconsin, Madison). J. Chem. Phys. 31, 1359-67 (1959). C.A. 54, 13827c.

Obtaining mixtures of ortho- and para-modifications of deuterium. A. I. Shal'nikov. Pribery i Tekh. Esperimenta 1959, No. 1, 150. C.A. 53, 16627 i.

L. S. Singer, W. J. Spry, and W. H. Smith, Proceedings of the Third Carbon Conference, Pergamon Press, Oxford, 1959, p. 121.

The heats of vaporization of parahydrogen and orthodeuterium from their boiling points to their critical temperatures. David White, Jih-Heng Hu, and Herrick L. Johnston (Ohio State Univ., Columbus). J. Phys. Chem. 63, 1181-3 (1959). C.A. 54, 60h.

G. A. Wolff and J. D. Broader, Acta Crystallogr., 12, 313 (1959).

Statistical mechanics of solid and liquid mixtures of ortho- and para-hydrogen. II. Agnessa Babloyantz and A. Bellemans (Univ. Brussels, Belg.). Mol. Phys. 3, 313-18 (1960); cf. C.A. 53, 19502h. C.A. 55, 11063i.

Second virial coefficients of ortho- and para-H₂ at liquid-H temperatures. J. J. M. Beenakker, F. H. Varekamp, and H. F. P. Knaap (Kamerlingh Onnes Lab., Leiden, Neth.). 26, 43-51 (1960) (In English). C.A. 54, 20385c.

Nuclear spin conservation in ortho-para hydrogen conversion. Doyle Britton and Z. Z. Hugus, Jr. (Univ. of Minnesota, Minneapolis) J. Chem. Phys. 33, 1830-2 (1960). C.A. 55, 17227i.

The extreme sensitivity of paramagnetic sites to poisoning by desorbed gases evaluated by the low-temperature ortho-parahydrogen conversion. Douglas S. Chapin, C. Dick Park, and Myron L. Corrin (Univ. of Arizona, Tucson). J. Phys. Chem., 64, 1073-4 (1960). C. A. 55, 3159 h.

Transformation of ortho- to parahydrogen over solid catalysts. II. Reaction in the liquid phase. R. A. Buyanov (Combined Inst. Nuclear Studies, Dubna). Kinetika i Kataliz 1, 418-20 (1960); cf. C.A. 55, 2245 c. C.A. 56, 49 a.

The ortho- and para-conversion of H on solid catalysts. III. Catalysis by rare earth hydroxides. R. A. Buyanov (Inst. Nuclear Research, Dubna). Kinetika i Kataliz 1, 617-19, (1960); cf. ibid. 418; C.A. 55, 2245 c.

Conversion of orthohydrogen to parahydrogen on solid catalysts at 78-64°K 1. R. A. Buyanov. Kinetika i Kataliz 1, 306-12 (1960) C.A. 55, 2245 c.

A kinetics study of ortho-para-hydrogen conversion. R. N. Keeler, D. H. Weitzel, J. H. Blake, and M. Konecnik (CEL Natl. Bur. of Standards, Boulder, Colo.), Advances in Cryogenic Eng. 5, 511-17 (1960). C.A. 55, 6109 e.

P. L. Barrick, D. H. Weitzel, and T. W. Connolly, in Advances in Cryogenic Engineering, Vol. 1. Plenum Press, New York (1960), p. 285.

L. Bonnetain, X. Duval, and M. Letort, Proceedings of Fourth Carbon Conference, Pergamon Press, Oxford, 1960, p. 107.

Buyanov, R. A., Kinet. Catal. (USSR) 1, 306 (1960).

Buyanov, R. A., Kinet. Catal. (USSR) 1, 578 (1960).

D. S. Chapin, C. D. Park, and M. L. Corrin, J. Phys. Chem., 64, 1073 (1960).

C. A. Coulson, Proceedings of the Fourth Carbon Conference, Pergamon Press, Oxford, 1960, p. 215.

Hydrous ferric oxide catalyst for converting ortho hydrogen to the para form. Dwyer, R. F., Burdsall, C. H., Union Carbide Corp., Pat. No. US 3,132,000, Date 28/11/60.

1960 Cont'd:

M. R. Eriksson, M. S. Thesis, University of Colorado, Boulder, Colorado (1960).

H. E. Farnsworth and J. Marsh, Bull. Amer. Phys. Soc., 5, 349 (1960).

Influence of strongly chemisorbed gases on the rates of the para-hydrogen conversion and the H₂-O₂ exchange over Ni and Cu + Ni alloy catalysts.

Hall, W. K.; Lutinski, F. E.; Hassell, J.E.; Mellon Inst., Pa. USA, Trans. Faraday Soc.; (64) 60 (502); p. 823-4; in Eng.

J. Koutecky and M. Tomasek, Phys. Rev., 120, 1212 (1960).

R. N. Keeler and K. D. Timmerhaus, Advances in Cryogenic Engineering, Vol. 4, K. D. Timmerhaus (ed.), Plenum Press, New York (1960), p. 296.

R. N. Keeler and K. D. Timmerhaus, Advances in Cryogenic Engineering, Vol. 4, Plenum Press, New York (1960), p. 302.

The catalytic activity of sodium tungsten bronzes. Loebel, E. M.; Jones, F. T.; Polytechnic Inst. Brooklyn, N.Y., USA, U.S. Dept. Com. Office Tech. Serv., PB Rept., 153, 147 (1960); in Eng.

Moore, W. R., Ward, H. R., J. Phys. Chem., 64, 832 (1960).

Moos, A. M., Ind. Eng. Chem., 52, 291 (1960).

S. Mrozowski and J. F. Andrew, Proceedings of the Fourth Carbon Conference, Pergamon Press, Oxford, 1960, p. 207.

L. Pauling, The Nature of the Chemical Bond, Cornell Univ. Press, New York, 1960.

J. R. Purcell, J. W. Draper, and D. H. Weitzel, Advances in Cryogenic Engineering, Vol. 3, K. D. Timmerhaus (ed.), Plenum Press, New York (1960), p. 191.

G. M. Schwab and E. Killman, Actes Congr. Int. Catal. 2nd, 1, 1047 (1960).

L. E. Scott, M. S. Thesis, University of Colorado, Boulder, Colorado (1960).

G. Wagoner, Phys. Rev., 118, 647 (1960).

G. Wagoner, Proceedings of the Fourth Carbon Conference, Pergamon Press, Oxford, 1960, p. 197.

D. H. Weitzel, J. W. Draper, O. E. Park, K. D. Timmerhaus, and C. C. Van Valin, Advances in Cryogenic Engineering, Vol. 2, K. D. Timmerhaus (ed.), Plenum Press, New York (1960), p. 12.

Conversion of ortho- to parahydrogen. Weitzel, D. H.; Loebenstein, W. V.; US Pat. No. 2,943,917; Date 5/07/60.

1960 Cont'd:

Compilation of thermodynamic properties, transport properties, and theoretical rocket performance of gaseous hydrogen. Charles R. King. NASA (Natl. Aeronat. Space Admin.) Tech. Note D-275, 71 pp. (1960). C.A. 54, 13789f.

Metastable hydrogen molecules. William Lichten (Univ. of Chicago). Phys. Rev. 120, 848-53 (1960). C.A. 55, 3186g.

Electron spin resonance (EPR) absorption of diphenylpicrylhydrazyl-zinc oxide mixtures. Y. Matsunaga and C. A. McDowell (Univ. Brit. Columbia, Vancouver). Can. J. Chem. 38, 724-7 (1960). C.A. 54, 19172a.

Gas-solid chromatography of H₂, HD, and D₂. Isotopic separation and heats of adsorption on alumina. William R. Moore and Harold R. Ward (Massachusetts Inst. of Technol., Cambridge). J. Phys. Chem. 64, 832 (1960). C.A. 54, 23600a.

Catalytic exchange H₂-D₂ on dicyclopentadienylnickel. Pavel Jiru and Karel Kuchynka (Czechoslov. Acad. Sci., Prague). Z. physik. Chem. (Frankfurt) 25, 286-7 (1960). C.A. 55, 5091b.

Separation of parahydrogen, orthohydrogen, hydrogen deuteride, orthodeuterium, and paradeuterium by gas adsorption chromatography. Takao Kwan (Hokkaido Univ., Sapporo). J. Research Inst. Catalysis, Hokkaido Univ. 8, 18-28 (1960); cf. C.A. 54, 2985n., C.A. 55, 60c.

Conversion of ortho- to parahydrogen. Daniel H. Weitzel and Wm. V. Loebenstein. U.S. 2,943,917, July 5, 1960. C.A. 54, 21683 c.

Theory of ortho-para hydrogen separation by adsorption at low temperatures, isotope separation. David White and Edwin N. Lassettre, J. Chem. Phys. 32, 72.84 (1960) C. A. 54, 11631 g.

Dear, J. W., A tabulation of the thermodynamic properties of normal hydrogen from low temperatures to 300°K and 1 to 100 atmospheres. NBS Technical Note 120 (1961).

J. F. Kucirka and G. E. Schmauch, "Investigation of the Para-Ortho Shift of Hydrogen", ASD Quarterly Progress Report IV, Contract No. AF 33(616)-7506 (July, 1961).

Johnson, V. J. (ed.). Properties of Materials at low temperatures (a compendium). Pergamon Press (1961).

Properties of Materials at Low Temperatures (a compendium). Johnson, V. J. (ed.), Pergamon Press (1961).

A tabulation of the thermodynamic properties of normal hydrogen from low temperatures to 300°K and from 1 to 100 atmospheres. Dean, J. W., NBS Technical Note 120; Nov. 1961.

Studies on heat transfer in packed beds. Yagi, S.; Kunii, D.; Int. Developments in Heat Transfer; p. 750; 1961 Part IV.

D. A. Seanor, Ph.D. thesis, Univ. of Bristol, England, 1961.

Vander Arend, P. C., Chem. Eng. Progr., 57, No. 10, 62 (1961).

Yagi, S. and Kunii, D. Studies on heat transfer in packed beds. Int. Developments in Heat Transfer, Part IV, 750 (1961).

Calculation of absolute reaction rates. O. K. Davtyan (I. I. Mechnikov State Univ., Odessa). Zhur. Fiz. Khim. 35, 1944-50 (1961) C.A. 56, 2026h.

Thermodynamic functions for parahydrogen. R. D. Goodwin, D. E. Diller, H. M. Roder, B. A. Younglove, and L. A. Weber (Natl. Bur. of Stds., Boulder, Colorado.). U.S. Dept. Com., Office Tech. Serv., AD 262,673 77 pp. (1961). C.A. 58, 6254d.

Heat conductivity of gaseous mixtures of para-ortho hydrogen at 20°K. K. Heinzinger, A. Klemm, and L. Waldmann (Max-Planck-Inst. Chem., Mainz, Ger.). Z. Naturforsch. 16a, 1338-42 (1961). C.A. 56, 14951h.

Radiation-induced effects in MgO catalysts. J. Hoigne and D. Ballantine (Brookhaven Natl. Lab. Upton, N.Y.). U.S. At. Energy Comm. BNL 686 (T-233). 31 pp. (1961) C.A. 56, 2915 f.

Statistical-mechanical analysis of catalyzed hydrogenation of olefins and associated reactions in the presence of metallic catalyst. Juro Horiuchi (Hokkaido Univ., Sapporo, Japan). Proc. Intern. Congr. on Catalysis, 2nd Paris, 1960 1, 1191-1210, discussion 1211 (Pub. 1961) (In English); cf. C.A. 29, 24318; 54, 23669f. C.A. 56, 982d.

Kinetics of para-ortho hydrogen conversion and the use of this reaction in the study of the mechanism of catalytic processes. S. L. Kiperman and I. R. Davydova, *Kinetika i Kataliz* 2, 762-72 (1961). C.A. 56, 12352 h.

Provisional thermodynamic functions for parahydrogen. Hans M. Roder and Robert D. Goodwill (Natl. Bur. of Stds., Boulder, Colo.), U.S. Dept. Com., Office Tech. Serv., P. B. Rept. 161,631, 142 pp. (1961). C.A. 58, 8460b.

Hydrogen Transport property correlations. J. D. Rogers, R. K. Zeigler, and P. C. McWilliams (Los Alamos Sci. Lab., Los Alamos, N. Mex.). U.S. At. Energy Comm. T10-12, 633. 17 pp. (1961). C.A. 59, 9343d.

Thermodynamic properties of 20.4°K -equilibrium hydrogen. A. Shaffer, and J. Rousseau (Ai Res. Manufg. Co., Los Angeles, Calif.). U.S. Dept. Com., Office Tech. Serv. AD 267, 262, 110 pp. (1961). C.A. 58, 72f.

The hindered energy exchange between solids and adsorbed gas molecules in the case of ortho-H and para-H. K. Schaefer and S. Stotz (Univ. Heidelberg, Ger.) *Z. Electrochem.* 65, 623-8 (1961); cf. C.A. 48, 5594f. C.A. 56, 8036b.

Gas chromatography of heavy hydrogen and ortho- and para-hydrogen. Takao Kan (Univ. Tokyo). *Kagaku no Ryoiki Zokan No.* 44, 97-113 (1961). C.A. 56, 2i.

Some electron and proton resonance studies in heterogeneous catalysis. John Turkevich, John Mackey, and W. H. Thomas. *Actes congr. intern catalyses*, 2^e, Paris, 1960 2, 1815-28, discussion 1829 (Pub. 1961). C.A. 55, 23012e.

Application of the reaction of para-ortho conversion in investigations of elementary stages of heterogeneous catalysis. V. E. Vasserberg, I. R. Davydova, and T. V. Georgievskaya. *Kinetika i kataliz* 2, 773-9 (1961). C.A. 56, 9466 i.

Formation of intermediate radical-like surface forms in heterogeneous catalysis. Vasserberg, V.E.; Balandin, A. A.; Davydova, I.R.; *Doklady Akad. Nauk. SSSR.*; (61) 136; p. 377-80.

CHEMABS patent 62007415g, Liquid parahydrogen, A. G. Zel'dovich, Yu. K. Pilipenko. USSR 166,373, Date 10/08/62.

64N27459#, Investigation of the para-ortho shift of hydrogen final report, Nov. 1962-Nov. 1963 (catalyst development for low temperature para-ortho conversion reaction of hydrogen). Biskis, E. G.; Kucirka, J. F.; Schmauch, G.E.

64N16608#, Investigation of para-ortho shift of hydrogen, final report, Mar.-Sept. 1962, (para-ortho shift of hydrogen endothermic heat conversion). Clark, R. G.; Jambhekar, A.; Kucirka, J. F.; Schmauch, G. E.

CHEMABS patent 63012377c, Catalysts and catalytic processes for hydrogen conversion. Weitzel, D. H.; Loebenstein, W. V.; Koeler, R. N.; Timmerhous, K. D.; UK 999,107, Date 24/04/62.

Clark, R. G., Kucirka, J. F., Jambhekar, A., Schmauch, G. E., "Investigation of the Para-Ortho Shift of Hydrogen", Air Products and Chemicals, Inc., Summary Technical Report ASD TR 62-833, Part I, July 1962.

Journal of Catalysis 1, 62-73 (1962).

M. Green and R. Seiwatz, J. Chem. Phys., 37, 459 (1962).

Drain, L. E., Proc. Phys. Soc., London 80, 1380 (1962).

Wakao, N., Smith, J. M., and Selwood, P. W., J. Catal. 1, 62 (1962).

Gas-chromatographic separation of ortho- and parahydrogen on molecular sieves. L. Bechmann, E. Bechtold, and E. Cremer (Univ. Innsbruck, Austria). J. Catalysis 1, 113-20 (1962). C.A. 57, 9267g.

Optimum effectiveness factors for porous catalysts. Cunningham, R. E.; Smith, J. H.; Univ. California, Davis, USA, A.I.Ch.E.J.; (63) 9; p. 419-21; in Eng.

Significant-structure theory of liquid hydrogen in its various ortho-para and isotopic forms. Douglas J. Henderson, Henry Eyring, and Dale Felix (Univ. of Utah, Salt Lake City). J. Phys. Chem. 66, 1128-32 (1962). C.A. 57, 7929g.

Ortho-parahydrogen conversion by metal surfaces at 21°K. J. T. Kummer (Ford Motor Co., Dearborn, Mich.). J. Phys. Chem. 66, 1715-19 (1962). C.A. 57, 14537f.

Metastable hydrogen molecules. II. Fine structure of para-hydrogen. William Lichten (Univ. of Chicago). Phys. Rev. 126, 1020-7 (1962); cf. C.A. 55, 3186g. C.A. 57, 6769h.

The effect of adsorbed oxygen on the catalytic activity of Pt and Pt-Au alloys in the parahydrogen conversion reaction. Hietrich Menzel and Lothar Riekert (Tech. Hochschule, Darmstadt, Ger.) Z. Elektrochem. 66, 432-9 (1962). C.A. 57, 10563 b.

Hydrogen transport property correlations. II. J. D. Rogers, R. K. Zeigler, and Paul McWilliams (Los Alamos Sci. Lab., Los Alamos, N. Mex.). U.S. At. Energy Comm. LA-2719, 40 pp. (1962); cf. J. Chem. Eng. Data 7, 179(1962). C.A. 58, 10750g.

Schmidt number for normal hydrogen and parahydrogen. S. C. Saxena and T. K. S. Narayanan (Rajasthan Univ., Jaipur, India). Can. J. Phys. 40, 527-30 (1962); cf. C.A. 55, 16052b. C.A. 57, 7925g.

Comparison of the isotope exchange between hydrogen and water, the parahydrogen conversion, and the combustion of oxyhydrogen gas in water suspensions of noble metal-charcoal catalysts. U. Schindewolf, M. Kenawy, and E. G. Mahadevan (Kernforschungs-zentrum, Karlsruhe, Ger.). Z. Elektrochem. 66, 406-12 (1962); C.A. 57, 10562 i.

Low-temperature, ortho-parahydrogen conversion; kinetic studies. Noriaki Wakao, P.O. Selwood and J. M. Smith (Northwestern Univ. Evanston, Ill.). A.I.Ch.E. (Am. Inst. Chem. Engrs.) J.8, 478-81 (1962). C.A. 57, 15863 a.

Low-temperature ortho-parahydrogen conversion kinetic studies. Wakao, N.; Selwood, P. W.; Smith, J. H.; Northwestern Univ., Evanston, Ill., USA, A.I.Ch.E.J.; (62) 8; p 478-81; in Eng.

The low-temperature orthohydrogen conversion over supported oxides and metals. Noriaki Wakao, J. M. Smith, and P. W. Selwood (Northwestern Univ., Evanston, Ill.). J. Catalysis 1, 62-73 (1962). C.A. 57, 1603 b.

Catalytic properties of semiconductors. Banks, E.; Collins, F. C.; Loeb1, E. M.; Sarfati, J.; Polytech. Inst. Brooklyn, USA; AD610780 Avail. CFSTI (1963); in Eng.

Gini D., Pinch, P. T., Von Wald, J. L., and Barrick, P. L. Advan Cryog Eng 8, 183 (1963).

Clark, R. G., J. F. Kucirka, A. Jambhekar, and G. E. Schmauch, "Investigation of the Para-Ortho Shift of Hydrogen," Tech. Doc. Rpt. No.; ASD-TDR-62-833, parts I & II, for A. F. Aero-Propulsion Lab, R. & Tech. Div., Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, Oct. 1963.

Schmauch, G. E., J. F. Kucirka, and R. G. Clark, "Activity Data on Improved Para-Ortho Conversion Catalysts," Chem. Eng. Prog., Vol. 59, No. 8, 55-60, Aug. 1963.

Eley, D. D., and Shooter, D., J. Catalysis, 2, 259-73 (1963).

N. R. Laine, F. J. Vastola, and P. L. Walker, Jr., J. Phys. Chem., 67, 2030 (1963).

Schmauch, G. E., Kucirka, J. F., Clark, R. G., "Activity Data on Improved Para-Ortho Conversion Catalysts," AICHE Symposium on Technical Aspects of Liquid Hydrogen Production, Buffalo, May 1963.

D. Gini, F. T. Finch, J. L. Von Wald, and P. L. Barrick, in Advance in Cryogenic Engineering, Vol. 8, Plenum Press, New York (1963), p. 183.

Szego, G., Cohn, E., Astronaut. Aerosp. Eng., 1, No. 4, 107 (1963).

M. J. Rossiter, R. N. Smith, and J. R. Ludden, J. Phys. Chem., 67, 2541 (1963).

N. R. Laine, F. J. Vastola, and P. L. Walker, Jr., Proceedings of the Fifth Carbon Conference, Vol. 2, Pergamon Press, Oxford, 1963, p. 211.

Ashmead, D. R., Eley, D. D., and Rudham, R., Trans. Faraday Soc. 59, 207 (1963).

"Activity Data on Improved Para-Ortho Conversion Catalysts", Schmauch, Kucirka, Clark (APCI), Chemical Engineering Progress, August 1963.

AF 33(657)-10796 Marquardt Oct 62-Nov 63 Conference on Heat Exchanger Fouling and Contaminant Removal.

"Continuous Conversion Hydrogen Liquefaction" Lipman, Cheung, Roberts, (Linde-UCC), Chemical Engineering Progress, August 1963.

Clark, R. G., J. F. Kucirka, A. Jambhekar, and G. E. Schmauch, "Investigation of the Para-Ortho Shift of Hydrogen," Tech. Doc. Rpt. No.; ASD-TDR-62-833, parts I & II, for A. F. Aero-Propulsion Lab, R. & Tech. Div., Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, Oct. 1963.

1963 Cont'd:

McKinley, C., Schmauch, G., "Effect of Adsorbed Nitrogen on Catalytic Activity of Ortho-Para Hydrogen Conversion Catalysts," Cryogenic Eng. Conf., Boulder, Colorado, August 1963.

"Investigation of the Para-Ortho Shift of Hydrogen," Technical Documentary Report No. ASD-TDR-62-833, by Air Products (R. G. Clark, Kucirka, Jambhekar, Schmauch) for Wright Patterson AFB, Part I July 1962, Part 2 October 1963.

"Investigation of the Para-Ortho Shift of Hydrogen," Clark, R. G.; Kuaraka, J. F.; Jambhekar, A.; Schmauch, G. E.; Wright-Patterson Air Force Base, Ohio USA, NASA Doc. N64-16608; (1963); 52 ps; in Eng.

"Catalytic investigations of alloys, XXIV. Para hydrogen conversion on silver-palladium alloys". Rienacker, G.; Engels, S.; Monatsber. Deut. Akad., Wiss Berlin; (63) 5, (11-12); p. 706-11.

"Ortho-para transition in molecular hydrogen". Raich, J. C.; Good, R. H., Ames. Iowa Lab., Iowa, USA, Proc. Midwest Conf. Theoret. Phys.; Notre Dame Ind.; (63); p. 295-7; in Eng.

Ortho- and paratritium. E. W. Albers, P. Harteck, and R. R. Reeves, Jr. (Rensselaer Polytechnic Inst., Troy, N.Y.). Z. Naturforsch 18a, 197-202 (1963) (in English). C. A. 58, 13149a.

Parahydrogen conversion on neodymium oxide. Ashmead, D. R.; Eley, D. D.; Rudham, R.; Univ. Nottingham, England. Trans. Faraday Soc.; (63) 59; p. 207-15; in Eng.

Chem. Eng. News 41 (20), 68-71 (1963).

CHEMABS journal 59013383e; "Parahydrogen conversion of the first transition series", Eley, D. D.; Shooter, D.; Univ. Nottingham, England. J. Catal.; (63) 2 (4); p 259-74; in Eng.

CHEMABS journal 58010716d; "Determination of para and ortho-hydrogen, hydrogen deuteride, and deuterium by gas chromatography". Fujita, K.; Kivan, T.; Univ. Tokyo, Japan. Bunseki Kagaku; (63) 12; p 15-20.

Activity, surface area, and weight loss correlations for hydrous ferric oxide catalyst. D. Gini, F. T. Finch, J. L. Von Wald, and P. L. Barrick (Univ. of Colorado, Boulder). Advan. Cryog. Eng. 8, 183-9 (1963). C.A. 59, 9312 a.

Pressure-density-temperature relations of freezing liquid para-hydrogen to 350 atmospheres. R. D. Goodwin and H. M. Roder (Natl. Bur. of Stds., Boulder, Colo.). Cryogenics 3(1), 12-15 (1963). C.A. 59, 9351f.

The theory of parahydrogen transformation by biradicaloids. H. Hartmann, G. Gliemann, and H. Gebler (Univ. Frankfurt/Main, Ger.). Chim. Acta 1, 144-54, (1963) (In German) C.A. 59, 1128b.

Microcatalytic studies of the hydrogenation of ethylene. I. The promoting effect of adsorbed hydrogen on the catalytic activity of metal surfaces. Hall, N. K.; Hassell, J. A.; J. Phys. Chem.; (63) 67; p 636-43; in Eng.

Chromatographic separation of the isotopic and nuclear-spin species of the hydrogens at low temperatures. Walter J. Hanbach and David White (Ohio State Univ., Columbus). J. Chim. Phys. 60, 97-9 (1963) (in English). C.A. 58, 11980h.

Determination of para- and orthohydrogen, hydrogen deuteride, and deuterium by gas chromatography. Katsuyoshi Fujita and Takao Kwan (Univ. Tokyo). Bunseki Kagaku 12, 15-20 (1963). C.A. 58, 10716d.

Endothermic conversion of parahydrogen to adsorbed equilibrium hydrogen below 20°K. George E. MacWood and Karl W. Boeddeker (Ohio State Univ., Columbus). J. Chem. Phys. 38 (11), 2779-80 (1963) C.A. 59, 9346 d.

Irradiation-induced effects in magnesium oxide catalysts. Moigne, J.; Ballentine, D. Brookhaven Natl. Lab., Upton, N.Y., USA, Intern. J. Appl. Radiation Isotopes (63) 14 (4); p221-9; in Eng.

Diffusion kinetics in heterogeneous catalysis. III. Disturbance of kinetic measurements by longitudinal diffusion. Kinetics of the para-hydrogen conversion. H. Noller, P. Andreu, and G. M. Schwab (Univ. Munich, Ger.) Z. Physik. Chem. (Frankfurt) 36, 179-98 (1963); cf. C.A. 59, 4583d, 1130a.

Diffusion resistances in alumina and silica catalysts. Rao, M. R.; Smith, J. H.; Univ. California, Davis, USA; A.I.Ch.E.J.; (63) 9 (4); p 485-90; in Eng.

The orthobaric densities of parahydrogen, derived heats of vaporization, and critical constants. H. M. Roder, D. E. Diller, L. A. Weber, and R. D. Goodwill (Natl. Bur. Stds., Boulder, Colorado) Cryogenics 3 (1), 16-22 (1963) C.A. 59, 9356a.

Activity data on improved para-ortho (H₂) conversion catalysts. G. E. Schmauch, J. F. Kucirka, and R. G. Clark, Chem. Eng. Progr. 59(8), 55-60 (1963). C.A. 59, 9370 e.

Parahydrogen conversion in solution. II. G. M. Schwab, J. Voitlaender, and V. Penka (Univ. Munich, Ger.) Z. physik. Chem. (Frankfurt), 36, 378-82 (1963); cf. C.A. 49, 7435 e; 51, 11022 b. C.A. 59, 9347 a.

Viscosity of hydrogen in the gaseous and liquid states for temperatures up to 5000°K. Leonard I. Stiel and George Thodos (Northwestern Univ., Evanston, Ill.). Ind. Eng. Chem., Fundamentals 2 (3), 233-7 (1963). C.A. 59, 4564d.

Szego, G., Cohn, E., Astronaut. Aerosp. Eng. 1, No. 4, 107 (1963).

Adsorption equilibriums and reaction sequences in heterogeneous catalytic reactions. Riekert, K.; Menzel, D.; Staib, M. Tech. Hochsch. Darmstadt, Ger. Proc. Intern. Cong. Catalysis 3rd, Amsterdam; (64) 1; p 387-93; p 394-5; in Eng.

Keith, Carl D.; Haley, Alfred J. Jr. Englehard Minerals and Chemicals Corp., USA, Pat. No. 3383176, Date 12/05/64.

The catalytic activity of the rare earth oxides for para hydrogen conversion and hydrogen-deuterium equilibration. Ashmead, D. R.; Eley, D. D.; Rudham, R. Univ. Nottingham, England. J. Catal.; (64) 3 (3); p 280-8; in Eng.

"The Application of the Para-Ortho Conversion Reaction of Hydrogen to Orbital Systems," Technical Documentary Report No. APL-TDK-64-43, by Air Products (A. Singleton, Kinard, Waring, Lapin) for Wright Patterson AFB, June 1964.

"Technical Aspects of Ortho-Para Hydrogen Conversion", Schmauch, Singleton (APCI), Industrial and Engineering Chemistry, May 1964.

Schmauch, G. E., and A. H. Singleton, "Technical Aspects of Ortho-Parahydrogen Conversion", Ind. and Eng. Chem., Vol. 56, No. 5, 20-31, May 1964.

Carlson, J. A., A. H. Singleton, and P. D. Stelts, "APACHI Air Enrichment System Study, Phase-1 Final Report," for Air Force Missile Devel. Center, Holloman Air Force Base, New Mexico, Nov. 10, 1964.

Stewart, R. and Roder, B.; "Technology and use of liquid hydrogen." Pergamon Press, p 379 (1964).

"Kinetics and diffusion study of the para-ortho shift of hydrogen". Barrick, P. L.; Brown, L. F.; Hutchinson, H. L. Univ. Colorado, Boulder, USA. (64) AD606495; Avail. OTS; 273 ps; in Eng. From: US Gov't. Res. Rept.; 39 (22), 17, (1964).

"Catalytic conversion of para hydrogen into ortho hydrogen on semiconductors." Briones, A. G., Rev. Real. Acad. Cienc. Exact. Fis. Nat. Madrid; (64) 58 (4); p 431-526; in Span.

"Effect of adsorbed nitrogen on catalytic activity of ortho-parahydrogen conversion catalysts. (Ortho-parahydrogen conversion catalytic activity reduction dependent on surface covered by adsorbed nitrogen)." McKinley, C.; Schmauch, G. Advances in Cryogenic Engineering, Volume 9. 1964, p 217-226.

Singleton, A. H., G. E. Kinard, R. W. Waring, A. Lapin, "The Applications of the Para-Ortho Conversion Reaction of Hydrogen to Orbital Systems," Tech. Doc. Rpt. No. APL-TDR-64-43, for Wright-Patterson Air Force Base, Air Force Propulsion Lab, June 1964.

"The Isotope Exchange between Hydrogen and Water," Mahadevan, E. G., Indian Inst. Technol., Madras, India. Indian J. Chem.; (64) 2 (1); p 1-5.

1964 Cont'd:

"Literature Survey of Orthohydrogen and Parahydrogen Research", Technical Documentary Report No. APL-TDR-64-81, by University of Colorado, Dept. CHE (Barrick, Brown) for Wright Patterson AFB, August 1964.

"Experimental Study of reaction kinetics for para-ortho-hydrogen at 20 to 80 K., Hutchinson, H. L.; Barrick, P. L.; Brown, L. F.; Adv. Cryo. Eng.; (64) 10A; 190-196.

"Radiation activation of para-ortho hydrogen catalysts quarterly progress report," Mar. - May 1964 (conversion rate of para-ortho hydrogen caused by paramagnetic ion on catalyst surface). Leffler, A. J.

65N26055#, "Radiation activation of para-ortho hydrogen catalysts quarterly progress report, Jun.-Aug. 1964 (radiation activation of para-ortho hydrogen catalysts)." Leffler, A. J.

65N26362#, "Radiation activation of para-ortho hydrogen catalysts technical report, Nov. 22, 1963-Dec. 22, 1964 (Increased activity of para-ortho hydrogen catalysts due to radiation)." Leffler, A. J.

Biskis, E. G., J. F. Kucirka, & G. E. Schmauch, "Investigation of the Para-Ortho Shift of Hydrogen," Tech. Doc. Rpt. No. APL-TDR-64-48, for A. F. Aero-Propulsion Lab., R. & Tech. Div., Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, March 1964.

"Technology and Uses of Liquid Hydrogen", Stewart, R.; Roder, B.; Pergamon Press 1964; p 379.

"APACHI Air Enrichment Study - Phase I Final Report," by Air Products (Carlson, Singleton, Stelts) for Holloman AFB, November 1964.

H. L. Hutchinson, M. S. Thesis, University of Colorado (1964), Appendix J.

Ashmead, D. R., Eley, D. D., and Rudham, R.; J. Catal. 3, 280 (1964).

Schmauch, G. E., and Singleton, A. H., "Technical Aspects of Ortho-Para Hydrogen Conversion," Ind. Eng. Chem., 56, 30 (1964).

Wakao, N. and Smith, J. M.; "Diffusion and reaction in porous catalyst." Ind. Eng. Chem. Fundam. 3, 123 (1964).

J. Marsh and H. E. Farnsworth, Surface Sci., 1, 3 (1964).

D. Brennan, Recent Progress in Surface Science, Vol. 2, (J. F. Danielli, K. G. A. Pankhurst, and A. C. Riddiford, eds.), Academic Press, New York, 1964, p. 57.

D. Pugh, Phys. Rev. Lett., 12, 390 (1964).

J. Koutecky, Angew. Chem., 76, 365 (1964).

1964 Cont'd:

H. P. Boehm, E. Diehl, W. Heck, and R. Sappok, Angew. Chem., **76**, 742 (1964).

Schmauch, G. E. and Singleton, A. H.; "Technical Aspects of Ortho-Para-Hydrogen Conversion." Ind. Eng. Chem., **56**, 2031 (1964).

"Diffusion and Reaction in Porous Catalysts." Wakao, N.; Smith, J. M.; Ind. Eng. Chem. Fundam.; (64) **3**; 123.

"Investigation of the para-ortho shift of hydrogen". Biskis, E. G.; Kuaranka, J. F.; Schmauch, G. E.; Air Products and Chemicals, Inc., Pa. USA, (64) AD603150; Avail. OTS; 123 ps; in Eng. From: US Gov't. Res. Rept. **39** (18), 15, (1964).

"Activation of hydrogen by poly(copper phthalocyanine)." Acres, G. J. K.; Eley, D. D.; Univ. Nottingham, England. Trans. Faraday Soc.; (64) **60** (498); p. 1157-69; in Eng.

"Ortho hydrogen-para hydrogen conversion (Review 103 refs.)" Engels, S.; Humboldt Univ., Berlin. Z. Chem.; (64) **4** (5); p 162-70; in Ger.

"Ortho-para transition in molecular hydrogen". Raich, J. C., Iowa State Univ., Iowa, USA, Univ. Microfilms Order No. 64-3889; 69 ps; in Eng.

"The preferential adsorption and heterogeneous spin conversion of the ortho hydrogen and para deuterium on alumina at 20.4°K." Eberhart, J. G., Ohio State Univ., Ohio, USA, Univ. Microfilms; Order No. 64-1253; in Eng.

S. Akhtar and H. A. Smith, "Separation and Analysis of Various Forms of Hydrogen by Adsorption and Gas Chromatography," Chem. Rev. **64**, 261-276 (1964). (A review with 101 references).

P. L. Barrick and L. F. Brown, "Literature Survey on o- and p-Hydrogen Research, 1929 to Oct. 1963", Rept. AD 605285, 68 pp. (1964). Available from the Office of Technical Service, U.S. Dept. of Commerce.

P. L. Barrick, L. F. Brown, and H. L. Hutchinson, "Study of Reaction Kinetics of para-ortho Conversion," Rept. AD 606495, 273 pp. (1964). Available from the Office of Technical Service, U.S. Dept. of Commerce.

J. L. Benson and W. H. Johnson, Jr., Phys. Rev. Letters **13** (24), 724-726 (1964).

R. G. Clark, J. F. Kucirka, A. Jambhekar, and G. E. Schmauch, NASA Doc. N64-16608, 52 pp.

U.S. Pat. 3,132,000 (1964), R. F. Dwyer and C. M. Birdsall, "Hydrous Ferric Oxide Catalyst for ortho-para Hydrogen Conversion".

E. G. Biskis, J. F. Kucirka, and G. E. Schmauch, "Report on Development of Catalysts for para-ortho Reaction," Rept. AD 603150, 123 pp. (1964). Available from the Office of Technical Services, U.S. Dept. of Commerce.

G. E. Schmauch and A. H. Singleton, "Review on ortho-para Hydrogen Conversion," Ind. Eng. Chem. **56** (5), 20-31 (1964).

Catalytic investigations of alloys. XXV. Conversion of para hydrogen on silver-palladium alloys. Rienacker, G.; Engels, S.; Humboldt Univ. Berlin, Z. Anorg. Allgen. Chem.; (65) 336 (506); p 259-69; in Ger.

The investigation on intermediate surface compounds occurring in elementary stages of heterogeneous catalytic reactions. Kiperman, S. L., Acad. Sci., Moscow. Proc. Intern. Congr. Catalysis 3rd; (65) 1; p 503-13; in Eng.

The pentacyanocobaltate (II) complex catalyst by means of the para-ortho hydrogen conversion and the hydrogen-deuterium exchange reaction. Mizuta, T.; Takao, K.; University of Tokyo, Nippon Kagaku Zasshi; (65) 86 (10); p 1010-14; in Jap.

The para hydrogen conversion over synthetic ruby. Selwood, P. W., Univ. California, Santa Barbara, USA, J. Am. Chem. Soc.; (65) 87 (8): p 1804-5; in Eng.

Kinetics and mechanism of the para hydrogen conversion on nickel. Koker, H.; Noller, H.; Univ. Munich, Germany; Ber. Bunsenges. Physik. Chem.; (65) 69 (8); p 703-10; in Ger.

Experimental study of reaction kinetics for paraorthohydrogen at 20 deg. to 80 deg. K. (Conversion of para hydrogen to ortho hydrogen at 20 to 80 degrees K and 20 to 1000 psig, using standard ferric oxide gel catalyst). Barrick, P. L.; Brown, L. F.; Hutchinson, H. L.; Advances in Cryogenic Engineering, Volume 10, Sections A-L; 1965, p 190-196.

Kinetics of the reaction $H + \text{para-H}_2 = \text{ortho-H}_2 + H$. Schulz, W. R.; LeRoy, D. J.; Univ. Toronto, Canada; J. Chem. Phys.; (65) 42 (11); p 3869-73; in Eng.

Para-ortho conversion of hydrogen. Haley, Alfred J., Jr.; Hindin, Saul G.; Engelhard Inds., Inc., East Newark; Sci. Tech. Aerospace Rept. 1965, 3(21), N65-33458. NASA (Nat. Aeronaut. Space Admin.) Access.; (65) p 35 pp; No. AD 468293; in Eng.

Transport studies of defect structure inorganic compounds. Heikes, Robert R.; Westinghouse Res. Labs., Pittsburgh; U.S. Gov't. Res. Develop. Rept. 1966, 41(14), 103; Technical Report, U.S. Gov't. Res. Dev. Rep.; (65) p 31 pp; No. AD 464733; in Eng.

Ortho-para hydrogen conversion and hydrogen-deuterium exchange in the presence of tetracyanopyrene-cesium complex. Kondo, T.; Inokuchi, H.; Wakayama, N.; Univ. of Tokyo; J. Chem. Phys.; (65) 43 (10), p 3766-7; in Eng.

Experimental study of reaction kinetic for para-ortho hydrogen at 20° and 80°K. Hutchinson, H. L.; Barrick, P. L.; Brown, L. F.; Univ. of Colorado, Boulder. Advan. Cryog. Eng.; (65) 10 (A-L); p 190-6; in Eng.

Improved ferric oxide gel catalysts for ortho- parahydrogen conversion. (Catalyst for ortho-para hydrogen conversion, investigating hydrous ferric oxide). Barrick, P. L.; Brown, L. F.; Cruse, R. L.; Hutchinson, H. L.; Advances in Cryogenic Engineering, Volume 10, Sections A-L, 1965, p 181-189.

Improved ferric oxide gel catalyst for ortho- para hydrogen conversion. Barrick, P. L.; Brown, L. F.; Hutchinson, H. L.; Cruse, R. L.; Univ. of Colorado, Boulder, Advan. Cryog. Eng.; (65) 10 (A-L); p 181-9; in Eng.

Briones, A. G.; Garcia de la Banda, J. F.; Inst. Quim. Fis. Quim., Madrid, Anales Real. Soc. Espan. Fis. Quim. (Madrid); Ser. B; (65) 61 (12); p 1179-86; in Span.

Radiation activation of para-ortho hydrogen catalysts. Leffler, A. J.; Authur Little Inc., Mass., USA; Rept.No. AFAPL-TR-65-9 Avail. AEC (Accession no. 32775); in Eng.; (1965).

Design of para-orthohydrogen catalytic reactors. Singleton, A. H.; Lapin, A.; Air Products and Chemicals, Inc.; Advan. Cryo. Eng.; (65) 11; p 617-30; in Eng.

Effect of poison of a nickel catalyst on the rate of the para-ortho conversion of hydrogen. Davydova, I. R.; Kiperman, S. L.; N. D. Zelinskii Inst. Org. Chem., Moscow. Zh. Fiz. Khim.; (65) 39 (1); p 18-20; in Russ.

Effect of sorption of oxygen on a nickel catalyst and of catalyst sintering on the kinetics of H para-ortho conversion and isotope exchange. Davydova, I. R.; Kiperman, S. L.; Kinetika i Kataliz; (65) 6 (1); p 137-43; in Russ.

Evaluation of reverse reaction in treatment of kinetic data. Kiperman, S. L.; Gadzhi-Kasumov, V. S.; N. D. Zelinskii Inst. Org. Chem., Moscow. Izv. Akad. Nauk. SSSR; Ser. Khim.; (65) (6); p 1110-3.

Barrett, M. F., and Barry, T. I., J. Inorg. Nucl. Chem. 27, 1483 (1965).

Barrick, P. L.; Brown, L. F.; Hutchinson, H. L.; and Cruse, R. L.; Improved ferric oxide gel catalyst for ortho-/para-hydrogen conversion. Advan. Cryog. Eng. 10 181 (1965).

Engelhard Report, "Investigation of the Para/Ortho Conversion of Hydrogen," Tech. Report AFAPL-TR-65-59, July 1965; and U.S. Patent #3,383,176, "Catalytic Process for Ortho/Para Hydrogen Conversion," May 14, 1965.

"Investigation of the Para-Ortho Conversion of Hydrogen", Technical Report AFAPL-TR-65-59, by Englehard (Haley, Hindin), for Wright Patterson AFB, July 1965.

S. Mrozowski, Carbon, 3, 305 (1965).

A. J. Leffler, J. Chem. Phys., 43, 4410 (1965).

1965 Cont'd:

T. Tanabe, T. Moriya, and S. Sugano, Phys. Rev. Lett. 15, 1023 (1965).

Singleton, A. H. and Lapin, A.; Design of para-/ortho-hydrogen catalytic converters. Advan. Cryog. Eng., 11 617 (1965).

Nature of the intermediate state of cyclohexane on nickel surface. Kiperman, S. L.; Davydova, I. R.; Gaidai, N. A.; Metody Issled. Katal. Katal. Reakts.; (65) p. 218-28; Vol. 1; in Russ.

Thermodynamic and related properties of para-hydrogen from the triple point to 100K at pressures to 340 atmospheres. Roder, H. M.; NBS Monograph; 94; Aug. 1965.

Theoretical calculation of the ortho-para hydrogen transition rate on a paramagnetic solid surface. Leffler, A.J.; Author D. Little Inc., Mass., USA; J. Chem. Phys.; (65) 43 (12); p 4410-15; in Eng.

Para-ortho conversion of hydrogen. Haley, Alfred J., Jr.; Hindin, Saul G.; Engelhard Inds., Inc., East Newark, N. J., USA, NASA (Nat. Aeronaut. Space Admin.) Access., AD 468293, 35 pp., Sci. Tech. Aerospace Rept. 1965, 3(21), N65-33458.

Nature of the intermediate state of cyclohexane on nickel surface. Kiperman, S. L.; Davydova, I. R.; Gaidai, N. A.; Metody Issled. Katal. Katal. Reakts., 1, 218-28.

Chem. Week 96 (26), 75 (1965).

Singleton, A. H., and A. Lapin, "Design of Para-Orthohydrogen Catalytic Reactors," (J-5), Adv. in Cryo. Eng., Vol. II, 617-630, Plenum Press, 1966.

Effects of electronic structure of palladium-silver alloys and Group VI elements on the parahydrogen conversion. Runk, Robert B.; State Univ. of New York, Albany. From: Diss. Abstr. B 1966, 27(5), 1445. Dissertation; (66) p 144 pp; in Eng.

Conversion and equilibration rates of hydrogen on nickel. Eley, D.; Norton, P. R.; Univ. of Nottingham, England. Disc. Faraday Soc.; (66) 41; p 135-48; in Eng.

Hydrogen-deuterium equilibration and parahydrogen conversion over ruby, chromia, and chromia on alumina. Selwood, P. W.; Univ. of Calif., Santa Barbara. J. Am. Chem. Soc.; (66) 88 (12); p 2676-80; in Eng.

Effect of neutron irradiation on catalysts for the ortho-para hydrogen reaction. Leffler, A. J.; Ostar, B.; Authur D. Little Inc., Mass., USA; J. Catal.; (66) 5 (1); p 74-80; in Eng.

Analysis of catalytic ortho-para hydrogen reaction mechanisms. Hutchinson, Harold L.; Univ. of Colorado, Boulder; From: Diss. Abstr. B 1966, 27(4), 1136. Dissertation, (66) p 218 pp; in Eng.

Catalytic investigation of alloys. XXX. Parahydrogen conversion on platinum-manganese alloys. Engels, Siegfried; Deut. Akad. Wiss. Berlin; Monatsber. Dtsch. Akad. Wiss. Berlin; (66) p 443-9; Vol. 8; No. 6-7; in Ger.

Catalytic studies on alloys. XXVII. Parahydrogen conversion on nickel-manganese alloys. Engels, Siegfried. Deut. Akad. Wiss. Berlin; Z. Anorg. Allg. Chem.; (66) p 201-10; Vol. 348; No. 3-4; in Ger.

Catalytic studies on alloys. XXVIII. Parahydrogen conversion on palladium-manganese alloys. Engels, Siegfried. Deut. Akad. Wiss. Berlin; Z. Anorg. Allg. Chem.; (66) p 211-18; Vol. 348; No. 3-4; in Ger.

Conversion of para hydrogen to ortho hydrogen using nickel/alumina catalyst. Alcorn, W. R.; Sherwood, T. K.; Mass. Inst. Tech., Cambridge, USA. J. Catal.; (66) 6 (2); p 288-307; in Eng.

Semiconductivity and catalytic activity. IV. Kinetics and mechanism of the conversion of para into ortho hydrogen catalyzed by Cr_2O_3 . Briones, A. G.; Garcia de la Banda, J. F.; Anales. Real. Soc. Espan. Fis. Quim. (Madrid); Ser. B.; (66) 62 (2); p 193-22; in Span.

P. W. Selwood, J. Am. Chem. Soc., 88, 2676 (1966).

Hydrogen-deuterium equilibration and para hydrogen and ortho deuterium conversion over palladium; kinetics and mechanisms. Schollen, J. F. F.; Limburg, Geleen, Neth. J. Catal.; (66) 5 (1); p 1-17; in Eng.

1966 Cont'd:

Glushkova, V. B., and Boganov, A. G., Izv. Akad. Nauk. SSSR Ser. Khim. No. 7
Eng. transl. p 1101 (1966).

R. N. Smith, D. A. Young, and R. A. Smith, Trans. Faraday Soc., 62, 2280
(1966).

"Investigation of the Para-Ortho Shift of Hydrogen", Technical Report AFAPL-TR
66-111, by Air Products (Singleton, Kucirka, Lapin) for Wright Patterson AFB,
September 1966.

AF 33(615)-1316, Air Products, May 64 - May 66, Secret Uncl/Conf., "Research
and Development Investigation of the P-O Shift of Hydrogen".

W. R. Alcorn and T. K. Sherwood, J. Catal., 6, 288 (1966).

J. J. F. Scholter and J. A. Konvalinka, J. Catal., 5, 1 (1966).

H. P. Boehm, Angew. Chem., 78, 617 (1966).

J. J. Lander and J. Morrison, Surface Sci., 4, 241 (1966).

H. Harker, J. T. Gallagher, and A. Parker, Carbon, 4, 401 (1966).

Kinetics of para-ortho conversion of hydrogen over various metal catalysts.
Kiperman, S. L.; N. D. Zelinski Inst. Org. Chem., Moscow; Kinetika i Kataliz;
(66) 7 (4); p640-9; in Russ.

Low temperature conversion of hydrogen on silver. Sandler, Y. L.; Durigon, D.
D.; Westinghouse Res. Lab., Pittsburgh, Pa., USA; Trans. Faraday Soc.; (66) 62
(517); p 215-21; in Eng.

CA66(24):108692d - Catalytic studies on alloys. XXVII. Parahydrogen
conversion on nickel-manganese alloys. Engels, Siegfried. Z. Anorg. Allg.
Chem., 348(3-4), 201-10 (1966).

CA66(24):108693e - Catalytic studies on alloys. XXVIII. Parahydrogen
conversion on palladium-manganese alloys. Engels, Siegfried. Z. Anorg. Allg.
Chem., 348(3-4), 211-18 (1966).

CA67(2):6371b - Transport studies of defect structure inorganic compounds.
Heikes, Robert R.; U.S. Gov. Res. Dev. Rep., AD 464733, 31 pp. Avail. CFSTI,
\$3 cy from U. S. Gov't. Res. Develop. Rept. 1966, 41(14), 103 70
(Crystallization and Crystal Structure).

CA66(10):41076k - Analysis of catalytic ortho-para hydrogen reaction
mechanisms. Hutchinson, Harold L. 218 pp. Avail. 66-9429, From: Diss.
Abstr. B 1966, 27(4), 1136.

CA66(16):69287d - Effects of electronic structure of palladium-silver alloys
and Group VI elements on the parahydrogen conversion. Runk, Robert B., 144
pp. Avail. 66-11,974. From: Diss. Abstr. B 1966, 27(5), 1445 (1966).

Hydrogen conversion with organic vapor under illumination. Anthracene and anthracene-trinitrobenzene complex. Inokuchi, Hiroo; Tsuda, Motoyuki; Kondo, Tamotsu. Univ. Tokyo, Tokyo. J. Catal.; (67) p 91-92; Vol. 8; No. 1; in Eng.

Catalytic reactions of hydrogen on titanium and silicon dioxides. Harris, Jesse Ray, Alfred Univ., Alfred. From: Diss. Abstr. B 1967, 28(4), 1446. Dissertation; (67) p 166, in Eng.

Hydrogen-deuterium equilibration and ortho-parahydrogen conversion on molecular sieves. Turkevich, John; Ciborowski, Stanislaw. Princeton Univ., Princeton. J. Phys. Chem.; (67) p 3208-17; Vol. 71; No. 10; in Eng.

Langmuir-Hinshelwood kinetics and the catalytic para-ortho hydrogen shift reaction. Hutchinson, Harold L.; Barrick, Paul L.; Brown, Lee Francis. Continental Oil Co., Ponca City. Chem. Eng. Prog., Symp. Ser.; (67) p 18-30; Vol. 63; No. 72; in Eng.

Paramagnetic catalysis of the ortho-para hydrogen conversion. Nielsen, Svend E.; Dahler, John S.; Univ. of Minnesota, Minneapolis. J. Chem. Phys.; (67) p 732-44; Vol. 46; No. 2; in Eng.

Parahydrogen conversion on metals, oxides, and sulfides. Schoennagel, Hans J. Max-Planck-Inst. Phys. Chem., Goettingen. Ber. Bunsenges. Phys. Chem.; (67) p 1060-7; Vol. 71; No. 9-10; in Ger.

Oxidation state of Cr_2O_3 and its catalytic activity in the conversion orthohydrogen parahydrogen. Valverde-Diez, Nilo. Rev. Real Acad. Cince. Exactas. Fis. Natur. Madrid; (67) p 255-330; Vol. 61; No. 2; in Span.

Catalytic studies on molecular sieves. Turkevich, John; Murakami, Yuichi; Nozaki, Fumio; Ciborowski, Stanislaw. Princeton Univ., Princeton. Chem. Eng. Prog., Symp. Ser.; (67) p 75-85; Vol. 63; No. 73; in Eng.

The parahydrogen conversion on palladium-silver alloy films. Rossington, David R.; Runk, Robert B. State Univ. of New York, Alfred. J. Catal.; (67) p 365-77; Vol. 7; No. 4; in Eng.

G. M. Arnold, Carbon, 5, 33 (1967).

K. Antonowicz, Carbon, 1, 111 (1967).

Hutchinson, H. L., Barrick, P. L., and Brown, L. F., Chem. Eng. Prog. Symp. Ser. No. 72 63, 18 (1967).

The Journal of Chemical Physics, Volume 46, Number 2, 15 January 1967.

Para hydrogen conversion on gold-manganese alloys. Engels, Siegfried. Monatsber. Dtsch. Akad. Wiss. Berlin; (67) p 202-3; Vol. 9; No. 3; in Ger.

1967 Cont'd:

Activated adsorption of hydrogens on aromatic-alkali-metal charge-transfer complexes. Inokuchi, Hiroo; Wakayama, Nobuyuki; Kondo, Tamotsu; Mori, Yoshihoro. Univ. of Tokyo, Tokyo. J. Chem. Phys.; (67) p 837-42; Vol. 46; No. 3; in Eng.

Nielsen, S. N., and Dahler, J. S., J. Chem. Phys. 46, 732 (1967).

Newton, C. L., "Hydrogen Production and Liquefaction," Chem. and Process Eng., 51-58, Dec. 1967.

Schieber, M., "Experimental Magnetochemistry," p. 302. North-Holland, Amsterdam, Wiley, New York, 1967.

Iron hydroxide-base catalyst for low-temperature conversion of ortho-hydrogen to para-hydrogen. Buyanov, R. A.; Krivoruchko, O. P.; Institute of Catalysis, Siberian Dept., Academy of Sciences, USSR, USSR. Pat. No. 218130 Date: 11/03/67.

Catalytic reactions of hydrogen on titanium and silicon dioxides (catalytic reactions of hydrogen on titanium and silicon dioxides). Harris, J. R.; Date: 1967, Coll: 166 P, Avail: Univ. Microfilms.

Singleton, A. H., Lapin, A., and Wenzel, L. A., Advances in Cryogenic Engineering, Vol. 13, 409-27 (1967).

CA66(16):69221c - Activated adsorption of hydrogens on aromatic-alkali-metal charge-transfer complexes. Inokuchi, Hiroo; Wakayama, Nobuyuki; Kondo, Tamotsu; Mori, Yoshihiro. J. Chem. Phys. 46(3), 837-42 (1967).

CA67(10):48984j - Hydrogen conversion with organic vapor under illumination. Anthracene and anthracene-trinitrobenzene complex. Inokuchi, Hiroo; Tsuda, Motoyuki; Kondo, Tamotsu; J. Catal., 8(1), 91-2 (1967).

CA68(26):117231s - Quantum-mechanical study of H + H₂ reactive scattering. Karplus, Martin; Tang, Kwong, Tin. Discuss. Faraday Soc., No. 44, 56-67 (1967).

CA66(10):41044y - Paramagnetic catalysis of the ortho-para hydrogen conversion. Nielsen, Svend E.; Dahler, John S.; J. Chem. Phys. 46(2), 732-44 (1967).

CA66(24):108704j - The parahydrogen conversion on palladium-silver alloy films. Rossington, David R.; Runk, Robert B. J. Catal., 7(4), 365-77 (1967).

CA67(16):76583w - Catalytic studies on molecular sieves. Turkevich, John; Murakami, Yuichi; Nozaki, Fumio; Ciborowski, Stanislaw. Chem. Eng. Prog., Symp. Ser., 63(7), 75-85, (1967).

CA68(20):90226j - Zeolites as catalysts I. Turkevich, John, Catal. Rev., 1(1), 1-35, (1967).

1967 Cont'd:

CA67(22):103027b - Hydrogen-deuterium equilibration and ortho-parahydrogen conversion on molecular sieves. Turkevich, John; Ciborowski, Stanislaw. J. Phys. Chem., 71(10), 3208-17, (1967).

CA67(24):111751y - Ortho-para conversion of hydrogen and deuterium diluted in solid HD. Urano, K.; Motizuki, Kazuko. Solid State Commun., 5(9), 691-3 (1967).

CA68(10):43593s - Parahydrogen conversion on metals, oxides and sulfides. Schoennagel, Hans. J. Ber. Bunsenges. Phys. Chem., 71(9-10), 1060-7 (1967).

CA69(2):5519k - Oxidation state of Cr₂O₃ and its catalytic activity in the conversion orthohydrogen < - > parahydrogen. Valverde Diez, Nilo. Rev. Real Acad. Cienc. Exactas, Fis. Natur. Madrid, 61(2), 255-330 (1967).

Activity and magnetic properties of transition metal hydroxides catalyzing the low-temperature conversion of ortho hydrogen to parahydrogen. Buyanov, R. A.; Krivoruchko, O. P.; Golovin, A. V.; Inst. Katal., Novosibirsk. Kinet. Katal.; (68) p 804-9; Vol. 9; No. 4; in Russ.

J. H. de Boer, The Dynamic Character of Adsorption, Oxford Univ. Press, London, 1968.

Cotton, F. A. and Wilkinson, G., Advanced Inorganic Chemistry, J. Wiley and Sons, Interscience, 2nd Ed (1968).

Golovin, A. V., and Buyanov, R. A., Kinet. Catal. (USSR) 9, 464, (1968).

M. Misono and P. W. Selwood, J. Am. Chem. Soc. 91, 1300 (1968).

S. Ohno and I. Yasumori, Bull. Chem. Soc. Jap., 41, 2227 (1968).

R. Sappok and H. P. Boehm, Carbon, 6, 573 (1968).

Y. Shigehara and A. Ozaki, J. Catal., 10, 183 (1968).

Journal of the American Chemical Society, 90:11, May 22, 1968.

Extrinsic field acceleration of the magnetic para hydrogen conversion. Kisono, Makoto; Selwood, P. W.; Univ. of California, Santa Barbara. J. Amer. Chem. Soc.; (68) p 2977-8; Vol. 90; No. 11; in Eng.

Application of theoretical diffusion models in the presence of a catalytic reaction. Sterret, J. S.; Brown, L. F. Univ. of Colorado, Boulder. A.I.Ch.E. (Amer. Inst. Chem. Eng.)J.; (68) p 696-702; Vol. 14; No. 5; in Eng.

Semiconductivity and catalytic activity. VI. Relations between conductivity and activity in the catalysis of the conversion of para- into orthohydrogen by chromium oxide. Valverde Diez, N.; Gamero Briones, Antonio; Garcia de la Banda, Juan F.; Inst. Quim. Fis. "Rocasolano" Madrid. An. Quim.; (68) p 245-53; Vol. 64; No. 3; in Span.

Semiconductivity and catalytic activity. V. Catalysis of the conversion of para- into orthohydrogen by chromium oxide at low temperatures. Valverde Diez, N.; Gamero Briones, Antonio; Garcia de la Banda, Juan F. Inst. Quim. Fis. "Rocasolano" Madrid. An. Quim.; (68) p 233-44; Vol. 64; No. 3; in Span.

A rate model for the low temperature catalytic ortho-parahydrogen reaction (low temperature ortho parahydrogen reaction rate). Singleton, A. H. Date: 1968, Coll: 146 P, Avail: Univ. Microfilms. Order No. 69-7360.

Mechanism of low-temperature conversion of ortho-hydrogen to para-hydrogen on a catalyst surface. Golovin, A. V.; Buyanov, R. A. Inst. Katal.; Novosibirsk. Kinet. Katal.; (68) p 464; Vol. 9; No. 2; in Russ.

Rate model for ortho-parahydrogen reaction on a highly active catalyst.
Singleton, A. H.; Lapin, A.; Wenzel, L.A. Air Products and Chemicals, Inc., Allentown, Advan. Cryog. Eng.; (68) p 409-27; Vol. 13; in Eng.

Preparation of a catalyst for the low-temperature conversion of ortho-hydrogen into para-hydrogen. Buyanov, R. A.; Krivoruchko, O.P.; Institute of Catalysis, Academy of Sciences, USSR, USSR. Pat. No. 253773, Date: 15/07/68.

Comparison of surface states of quartz, cristobalite, and silicic acid.
Harris, J. R.; Rossington, D. R.; Coll. of Ceram., State Univ. of New York, Alfred. J. Amer. Ceram. Soc.; (68) p 511-18; Vol. 51; No. 9; in Eng.

Catalytic behavior of organic semiconductors. Relation between reactivity and valency of aromatic anion in aromatic-alkali metal complexes. Wakayama, Nobuyuki; Mori, Yoshihiko; Inokuchi, Hiroo. Univ. Tokyo, Tokyo. J. Catal.; (68) p 15-18; Vol. 12; in Eng.

Activity of glass and the method for its deactivation in para-ortho-conversion reactions and the isotopic exchange of hydrogen. Peretyaka, A. R.; Danchevskaya, M. N.; USSR; Vestn. Mosk. Univ., Khim.; (68) p 94-6; Vol. 23; No. 3; in Russ.

Singleton, A. H., Lapin, A. and Wenzel, L. A. Rate model for ortho-/para-hydrogen reaction on a highly active catalyst. Advan Cryog Eng, 13 409 (1968).

Singleton, A. H., A. Lapin, and L. A. Wenzel, "Rate Model for Ortho-Parahydrogen Reaction of a Highly Active Catalyst," Adv. in Cryo. Eng., Vol. 13 (F-7), Plenum Press, 409-427, 1968.

Journal of the American Chemical Society, 90:11, May 22, 1968.

Iron oxide and hydroxide as catalysts for low-temperature conversion of ortho-hydrogen to para-hydrogen. Buyanov, R. A.; Krivoruchko, O. P.; Kefeli, L. M.; Ostan'kovich, A. Inst. Katal., Novosibirsk. Kinet. Katal.; (68) p 379-85; Vol. 9; No. 2; in Russ.

Catalysis on single crystals. V. Parahydrogen conversion on nickel and copper single crystals. Voelter, J.; Jungnickel, H.; Rienecker, G. Deut. Akad. Wiss. Berlin, Berlin. Z. Anorg. Allg. Chem.; (68) p 300-6; Vol. 360; No. 5-6; in Ger.

Iron oxide and hydroxide as catalysts for low-temperature conversion of ortho-hydrogen to para-hydrogen. Buyanov, R. A.; Krivoruchko, O. P.; Kefeli, L. M.; Ostan'kovich, A. A. Kinet. Katal. 9(2), 379-85, (1968).

Activity and magnetic properties of transition metal hydroxides catalyzing the low-temperature conversion of ortho hydrogen to parahydrogen.
Buyanov, R. A.; Krivoruchko, O. P.; Golovin, A. V. Kinet. Katal., 9(4), 804-9 (1968).

1968 Cont'd:

Catalysis by palladium-gold and related alloys.

Eley, Daniel D.

J. Res. Inst. Catal., Hokkaido Univ., 16(1), 101-14, (1968).

Hydrogen conversion and restorage work cycle.

Goldstein, Allen E.; Rouse, Robert W.; Schroeter, Thomas T.

Marquardt Corp., U.S. US 3389555, 25 June 1968, 6 pp.

Mechanism of low-temperature conversion of ortho-hydrogen to para-hydrogen on a catalyst surface.

Golovin, A. V.; Buyanov, R. A.

Kinet. Katal., 9(2), 464, (1968).

Catalytic Activity of a Nickel-thoria Material.

Goue, Bernard; Charbonnier, Jean C.

C. R. Acad. Sci., Paris, Ser. C, 267(18), 1097-8 (1968).

Catalytic activity of a nickel-beryllium alloy.

Goue, Bernard; Guitard, Louis; Edon, Claude

C. R. Acad. Sci., Paris, Ser. C 266(19), 1413-15 (1968).

Study of verdazyl radicals in benzene solution by the para-hydrogen method.

Hartmann, Hermann; Brauer, Hans D.; Schaefer, Hugo

Z. Phys. Chem. (Frankfurt am Main) 62(1-4), 103-11 (1968).

Comparison of surface states of quartz, cristobalite, and silicic acid.

Harris, J. R.; Rossington, D. R.

J. Amer. Ceram. Soc., 51(9), 511-18, (1968).

Extrinsic field acceleration of the magnetic para hydrogen conversion.

Misono, Makoto; Selwood, P. W.

J. Amer. Chem. Soc., 90(11), 2977-8 (1968).

Conversion and exchange reactions of hydrogen over zinc oxide.

Otsuka, Kiyoshi; Keii, Tōinaga

Nippon Kagaku Zasshi, 89(11), 1032-6 (1968).

Kinetic studies of the catalytic ortho-para hydrogen conversion and hydrogen-deuterium equilibration on gamma-alumina.

Ohno, Seigo; Yasumori, Iwao

Bull. Chem. Soc. Jap., 41(10), 2227-33 (1968).

Activity of glass and the method for its deactivation in para-ortho-conversion reactions and the isotopic exchange of hydrogen.

Peretyaka, A. R.; Danchevskaya, M. N.

Vestn. Mosk. Univ., Khim., 23(3), 94-6 (1968).

Para-ortho transitions in solid hydrogen.

Schott, W.; Rietschel, H.; Glaeser, W.

Phys. Lett., A, 27(8), 566-7.

1968 Cont'd:

Hydrogen adsorption and parahydrogen conversion over chromia supported on .alpha.-alumina.

Selwood, Pierce W.

J. Catal., 12(3), 263-71 (1968).

Application of theoretical diffusion models in the presence of a catalytic reaction.

Sterrett, J. S.; Brown, L. F.

A.I.Ch.E. (Amer. Inst. Chem. Eng.)J., 14(5), 696-702 (1968).

Production of para-hydrogen.

Vander Arend, Peter C.

Air Products and Chemicals, Inc.

U.S. US 3375076, 26 Mar 1968, 4 pp.

Semiconductivity and catalytic activity. V. Catalysis of .n conversion of para- into orthohydrogen by chromium oxide at low temperatures.

Valverde Diez, N.; Gamero Briones, Antonio; Garcia de la Banda, Juan F.

An. Quim., 64(3), 233-44 (1968).

Semiconductivity and catalytic activity. VI. Relations between conductivity and activity in the catalysis of the conversion of para- into orthohydrogen by chromium oxide.

Valverde Diez, N.; Gamero Briones, Antonio; Garcia de la Banda, Juan F.

An. Quim., 64(3), 245-53, (1968).

Catalysis on single crystals. V. Parahydrogen conversion on nickel and copper single crystals.

Voelter, J.; Jungnickel, H.; Rienaecker, G.

Z. Anorg. Allg. Chem., 360(5-6), 300-6 (1968).

Catalytic behavior of organic semiconductors. Relation between reactivity and valency of aromatic anion in aromatic-alkali metal complexes.

Wakayama, Nobuyuki; Mori, Yoshihiro; Inokuchi, Hiroo.

J. Catal., 12, 15-18 (1968).

Rate model for the low temperature catalytic orthoparahydrogen reaction.

Singleton, Alan H.

Lehigh Univ., Bethlehem.

From: Diss. Abstr. B. 1969, 29(11), 4154.

Dissertation; (68) p 146 pp; in Eng.

Low-temperature conversion of ortho-hydrogen into para-hydrogen.

Buyanov, R. A.; Krivoruchko, O. P.
Institute of Catalysis, Academy of Sciences, USSR.
USSR.
Pat. No. 259835 Date: 19/02/68

Paramagnetic conversion of parahydrogen on neodymium and dysprosium oxides.

Errett, Ellis B.
Univ. California, Santa Barbara.
From: Diss. Abstr. Int. B 1971, 31(8), 4610.
Dissertation; (69) p 103 pp; in Eng.

Heterogeneous ortho-para hydrogen conversion.

Ilisca, Ernest.
Agence Nationale de Valorisation de la Recherche.
Ger. Offen. (170970)
Pat. No. 2012053 Date: 14/03/69.

Jones, F. T., and Loebel, E. M., J. Phys. Chem. 73, 894 (1969).

G. C. Michael, Ph.D. thesis, The Pennsylvania State Univ., University Park, 1969.

Misono, M., and Selwood, P. W., J. Amer. Chem. Soc. 90, 2977 (1968); 91, 1300 (1969).

Pearce, D. R., Richardson, P. C., and Rudham, R., Proc. Roy. Soc. Ser. A 310, 121 (1969).

Wakao, N., Kimura, H. and Shibata M. Kinetic studies and effective diffusivities in para- to ortho-hydrogen conversion reaction. J. Chem. Eng., Japan 2 51 (1969).

P. L. Walker, Jr., R. C. Bansal, and F. J. Vastola, The Structure and Chemistry of Solid Surfaces, Wiley, New York, 1969, p. 81.

Hydrogen isotope equilibration on gadolinium films.

Eley, Daniel D.; Norton, P. R.
Nottingham Univ.
Z. Phys. Chem. (Frankfurt am Main); (69) p 145-53; Vol.64; No. 1-4; in Eng.

Catalytic studies of alloys. XXXIII. Para-hydrogen conversion on copper-manganese and silver-manganese alloys.

Engels, Siegfried.
Deut. Akad. Wiss. Berlin, Berlin.
Z. Anorg. Allg. Chem.; (69) p 291-304; Vol. 366; No. 5-6; in Ger.

Catalytic studies on alloys. XXXII. Para-hydrogen conversion on platinum-manganese alloys.

Engels, Siegfried.
Zentralinst. Phys. Chem. deut. Akad. Wiss., Berlin.
Z. Anorg. Allg. Chem.; (69) p 220-30; Vol. 366; No. 3-4; in Ger.

1969 Cont'd:

Catalytic studies of alloys. XXXIV. Para-hydrogen conversion on gold-manganese alloys.

Engels, Siegfried; Engels, Siegfried.

Deut. Akad. Wiss. Berlin, Berlin.

Z. Anorg. Allg. Chem.; (69) p 305-15; Vol. 366; No. 5-6; in Ger.

Hydrogen reaction mechanisms on titanium dioxide.

Harris, Jesse R.; Rossington, David R.

State University of New York, New York.

J. Catal.; (69) p 168-74; Vol. 14; No. 2; in Eng.

Low-temperature catalytic conversion of ortho-hydrogen to para-hydrogen.

Golovin, A. V.; Guyanov, R. A.

Inst. Katal., Novosibirsk.

Kinet. Katal.; (69) p 113-17; Vol. 10; No. 1; in Russ.

Orthohydrogen-parahydrogen conversion and hydrogen-deuterium equilibration on sodium tungsten bronzes.

Jones, Francis, Thomas; Loeb, Ernest M.

Polytech. Inst. of Brooklyn, Brooklyn.

J. Phys. Chem.; (69) p 894-9; Vol. 73; No. 4; in Eng.

Hydrogen conversion study of the catalytic activation of gamma-alumina.

Minones Trillo, J.; Vilchez, J. C.; Gonzalez, Garcia, F.

Fac. Cienc., Univ. Sevilla, Sevilla.

An. Quim.; (69) p 841-8; Vol. 55; No. 11; in Span.

Extrinsic field acceleration of the magnetic parahydrogen conversion.

Misono, Makoto; Selwood, Pierce W.

Univ. of California, Santa Barbara.

J. Amer. Chem. Soc.; (69) p 1300-3; Vol. 91; No. 6; in Eng.

Catalytic behavior of organic semiconductors. Hydrogen exchange on aromatic-alkali metal complexes as a function of donor metals.

Mori, Yoshihiro; Wakayama, Nobuyuki; Inokuchi, Hiroo.

Univ., Tokyo, Tokyo.

J. Catal.; (69) p 1-3; Vol. 14; No. 1; in Eng.

Parahydrogen enrichment and hydrogen-deuterium equilibration at low temperatures on oxides of the first transition series.

Pearce, Derek R.; Richardson, Peter Charles; Rudham, Robert.

Univ. Nottingham, Nottingham.

Proc. Roy. Soc., Ser. A; (69) p 121-35; Vol. 310; No. 1500; in Eng.

Physical properties and catalytic activities of vanadium oxide (III) catalyst.

Tarama, Kimio; Teranishi, Shiihiro; Hattori, Kentaro; Yasui, Akio.

Dep. Hydrocarbon Chem., Kyoto Univ., Kyoto.

Mem. Fac. Eng., Kyoto Univ.; (69) p 611-20; Vol. 31; No. Pt. 4; in Eng.

1969 Cont'd:

Kinetic studies and effective diffusivities in para- to orthohydrogen conversion reaction.

Wakao, Noriaki; Kimura, Hiroshi; Shibata, Manabu.

Yokohama Nat. Univ., Yokohama.

J. Chem. Eng. Jap.; (69) p 51-4; Vol. 2; No. 1; in Eng.

Pressure-volume isotherms of hydrogen gas between 19 and 23°K.

El Hadi, Z. E. H. A.; Dorrepaal, J. A.; Durieux, M.

Physica, 41(2), 320-31 (1969).

General properties of multidimensional potential surfaces of chemical reaction. I. Models of complex adiabatic and nonadiabatic reactions.

Krivoshei, I. V.

Zh. Strukt. Khim., 10(2), 316-19 (1969).

Miniature heat exchanger for simultaneous para-orthohydrogen conversion and heat transfer.

Meier, Richard N.; Marple, John R.; Lee, Chau J.

Air Products and Chemicals, Inc.

Allentown, Pa., USA

Advan. Cryog. Eng., Volume Date 1968, 14, 185-93 (1969).

R. C. Bansal, F. J. Vastola, and P. L. Walker, Jr., Carbon, **8**, 443 (1970).

R. C. Bansal, F. J. Vastola, and P. L. Walker, Jr., J. Colloid Interface Sci. **32**, 187 (1970).

Para-hydrogen conversion on 5 Ang. molecular sieve and 5 Ang. molecular sieve c containing neodymium ions.

Brown, David Emmerson; Eley, Daniel D.; Rudham, R.
J. Catal.; (70) p 292-302; Vol. 16; No. 3; in Eng.

Parahydrogen conversion studies on gadolinium and yttrium and their oxides.
Capozzi, Victor F.

From: Diss. Abstr. Int. B 1970, 30(7), 3145.
Dissertation; (69) p 204 pp; in Eng.

Mechanism of the low-temperature catalytic conversion of o-hydrogen into p-hydrogen with unpairing nuclear spins.

Golovin, A. V.; Buyanov, R. A.
Kinet. Katal.; (70) p 957-61; Vol. 11; No. 4; in Russ.

Comparison of rate expressions for the low-temperature para-orthohydrogen shift.

Hutchinson, H. L.; Brown, L. F.; Barrick, P. L.
Advan. Cryog. Eng., Volume Date 1970, 16, 96-103.

Experimental evidence for a new effect in ortho-para molecular hydrogen conversion on magnetic surfaces.

Ilisca, E.
Phys. Lett. A; (70) p 247-8; Vol. 33; No. 4; in Eng.

Theoretical calculation of a new effect in ortho-para hydrogen conversion on magnetic surface.

Ilisca, E.
Phys. Rev. Lett.; (70) p 797-8; Vol. 24; No. 15; in Eng.

Kauffman, D., Ph.D. thesis, University of Colorado, Boulder, 1970.

Entropy of information from catalytic systems.

Kobozev, N. I.; Strakhov, B. V.
Khim. Fak., Mosk. Gos. Univ. im Lomosova
Moscow, USSR
Osn. Predvideniya Katal. Deistviya, Tr. Mezhdunar. Kongr. Katal., 4th, Meeting
Date 1968, Volume 2, 307-14. Edited by: Eidus, Ya. T. "Nauka": Moscow, USSR
(1970).

Catalytic properties of metallic yttrium, its hybriide, carbide, and oxide in the high-temperature para-ortho conversion of hydrogen.

Konenko, I. R.; Nadzhim, A.; Toistopyatova, A. A.; Makarenko, G. N.; Samsonov, G. V.
Izv. Akad. Nauk SSSR, Ser. Khim., (12), 2710-16 (1970).

Effect of conditions for ferric oxide and hydroxide preparation on their properties and catalytic activity during the low-temperature conversion of the ortho-hydrogen into para-hydrogen.

Krivoruchko, O. P.; Buyanov, R. A.

Kinet. Katal.; (70) p 524-30; Vol. 11; No. 2; in Russ.

Addition compounds of boron nitride with alkali metals and their catalytic activity.

Mugiya, Chie; Lhigashi, Noriko; Mori, Yoshihiro; Inokuchi, Hiroo.

Bull. Chem. Soc. Jap.; (70) p 287-8; Vol. 43, No. 1; in Eng.

Nitrous oxide decomposition and low temperature parahydrogen enrichment on pure and doped rutile.

Richardson, P. C.; Rudham, R.; Twist, W.; Wagstaff, K. P.

Trans. Faraday Soc.; (70) p 1773-82; Vol. 66; No. 7; in Eng.

Chemisorption and migration of hydrogen on sapphire (α -Al₂O₃) and ruby [(Cr, Al)₂O₃].

Selwood, P. W.

University of California, Santa Barbara, Calif., USA

Osn. Predvideniya Katal. Deistviya, Tr. Mezhdunar. Kongr. Katal., 4th, Meeting Date 1968, Volume 2, 235-42. Edited by: Eidus, Ya. T. "Nauka" Moscow, USSR (1970).

Mechanically activated catalysts. X. Copper(II) oxide as the catalyst for the ortho-para-hydrogen conversion.

Schrader, Richard; Fritsche, Bernd.

Z. Anorg. Allg. Chem.; (70) p 17-24; Vol. 379; No. 1; in Ger.

Sites active for catalytic hydrogen-deuterium equilibration over alpha-chromia.

Selwood, Pierce W.

J. Amer. Chem. Soc.; (70) p 39-49; Vol. 92; No. 1; in Eng.

Extrinsic field conversion of parahydrogen over the rare earths.

Selwood, Pierce W.

J. Catal.; (70) p 353-9; Vol. 19; No. 3; in Eng..

Effect of low magnetic fields on the catalyzed parahydrogen conversion rate over certain rare earths.

Selwood, Pierce W.

Nature (London); (70) p 278; Vol. 228; No. 5268; in Eng.

Chemisorption and migration of hydrogen on sapphire (α -Al₂O₃) and ruby (Cr, Al)₂O₃.

Selwood, P. W.

Document type: conference; Osn. Predvideniya Katal. Deistviya, Tr. Mezhdunar. Kongr. Katal., 4th; (70) p 235-42; Vol. 2; in Russ.

Selwood, P. W., Nature (London), 228, 278 (1970).

1970 Cont'd:

S. Sugano, T. Tanabe, and H. Kamimura, Multiplets of Transition-Metal Ions in Crystals, (Academic, New York, 1970).

Catalytic activity and reactivity of aromatic nitrile and alkali metal ion radical salt. I. Homogeneous and heterogeneous catalysis of benzonitrile-cesium ion radical salt.

Inst. Solid State Phys., Univ. Tokyo, Tokyo.

Bull. Chem. Soc. Jap.; (70) p 3410-14; Vol. 43; No. 11; in Eng.

Catalytic activity and reactivity of aromatic nitrile and alkali metal ion radical salt. II. Hydrogen exchange on benzonitrile ion salt as a function of alkali metals.

Tsuda, Motoyuki

Bull. Chem. Soc. Jap.; (70) p 3415-19; Vol. 43; No. 11; in Eng.

Hydrogen held by solids. 17. Ortho-para H₂ conversion and H₂-D₂ exchange reactions over a transition alumina.

Van Cauwelaert, Frans H.; Hall, W. Keith.

Trans. Faraday Soc.; (70) p 454-68; Vol. 66; No. 2; in Eng.

R. C. Bansal, F. J. Vastola, and P. L. Walker, Jr., Carbon, 9, 185 (1971).

A. J. Bennett, B. McCarroll, and R. P. Messmer, Phys. Rev. B, 3, 1397 (1971).

Investigation of Wittig's hydrocarbon in benzene solution by the para-ortho hydrogen conversion.

Brauer, Hans. D.

Chem. Ber., 104(3), 909-12 (1971).

Application of the para- to orthohydrogen conversion reaction to the study of the recrystallization phenomena of a ternary iron-chromium-nickel alloy.

Criado, J. M.; Herrera, E. J.; Trillo, J. M.

An. Quim.; (71) p 973-9; Vol. 67; No. 11; in Span.

Application of the ortho-para hydrogen conversion: oxygen film adsorbed on graphite.

Derichbourg, Jacques; Duval, Xavier.

C.R. Acad. Sci., Ser. C; (71) p 980-2; Vol. 272; No. 11; in Fr.

Spin centers and catalysis on .gamma.-alumina.

Eley, Daniel D.; Zammitt, M. A.

J. Catal., 21(3), 366-76 (1971).

Spin centers and catalysis on magnesia.

Eley, Daniel D.; Zammitt, M. A.

J. Catal., 21(3), 377-83 (1971).

Paramagnetic conversion of parahydrogen on neodymium and dysprosium oxides.

Errett, Ellis B., University of California, Santa Barbara, Calif., USA

103 pp. Avail. Univ. Microfilms, Ann Arbor, Mich., Order No. 70-24,233

From: Diss. Abstr. Int. B 1971, 31(8), 4610.

Comparison of rate expressions for the low-temperature para-orthohydrogen shift.

Hutchinson, H. L.; Brown, L. F.; Barrick, P. L.

Advan. Cryog. Eng.; (71) p 96-103; Vol. 16; in Eng.

Catalytic activity of organic semiconductors and enzymes.

Inokuchi, Hiroo.

Discuss. Faraday Soc.; (71) p 183-9; Vol. No. 51; in Eng.

Parahydrogen conversion and hydrogen-deuterium equilibration over carbon surfaces.

Ishikawa, Yuichi.

From: Diss. Abstr. Int. B 1972, 32(9), 5296.

Dissertation; (71) p 155 pp; in Eng.

Catalytic properties of rare-earth metals (scandium, neodymium), their hydrides, carbides, and oxides in the high-temperature para-ortho conversion of hydrogen.

Konenko, I. R.; Nadzhm, A.; Tolstopyatova, A. A.; Samsonov, G. V.; Makarenko, G. N. Izv. Akad. Nauk SSSR, Ser. Khim., (1), 100-5 (1971).

1971 Cont'd:

Kubicka, H., J. Catalysis, 20, No. 2, 163-71 (Feb. 1971).

Catalyst for ortho- and para-hydrogen conversion.

Nishimura, Yusaku; Nakajima, Fumito.

Hitachi Ltd.

Japan, Kokai.

Pat. No. 73 59090 Date: 30/11/71.

Quantum diffusion in solid hydrogen and deuterium.

Oyarzun, R.; Van Kranendonk, J.

Phys. Rev. Lett., 26(11), 646-8 (1971).

Catalysis by metal vapors. V. The para-hydrogen-ortho-hydrogen transformation.

Peretyaka, A. R.; Danchevskaya, M. N.; Kobozev, N. I.

Zh. Fiz. Khim., 45(3), 606-9 (1971).

Magnetic ortho-para conversion of hydrogen on the surface of nonstoichiometric uranium oxides.

Romanowski, Wladyslaw; Wozniakowski, Boguslaw.

Rocz. Chem.; (71) p 1549-57; Vol. 45; No. 9; in Eng.

Mechanically activated catalysts. XII. Methods for mechanical activation production of nickel catalysts.

Schrader, Richard; Staedter, Werner; Oettel, Heinrich.

Chem. Tech. (Leipzig), 23(6), 363-7 (1971).

Effect of a weak magnetic field on the rare earth-catalyzed parahydrogen conversion rate.

Selwood, P. W.

J. Catal.; (71) p 123-9; Vol. 22; No. 1; in Eng.

Hydrogen chemisorption and migration on sapphire, .alpha.-Al₂O₃, and on ruby (Cr,Al)₂O₃.

Selwood, P. W.

Proc. Int. Congr. Catal., 4th, Meeting Date 1968, Volume 2, 248-56. Akad.

Kiado: Budapest, Hung.

Catalytic activity and selectivity of low-temperature adsorption in the series of ortho-para modifications of hydrogen on synthetic zeolites.

Zhun, G. G.; Blagoi, Yu. P.

Tr. Fiz. - Tekh. Inst. Nizk. Temp., Akad. Nauk Ukr. SSR; (71) p 109-13, Vol. No. 15; in Russ.

Hydrogen chemisorption and exchange on platinum.

Breakspere, R. J.; Eley, D. D.; Norton, P. R.
Chem. Dept., Nottingham Univ., Nottingham, Eng.
J. Catal., 27(2), 215-21 (1972).

Extrinsic magnetic field effect on parahydrogen and orthodeuterium conversion catalyzed by neodymium oxide.

Eley, D. D.; Forrest, H.; Pearce, D. R.; Rudham, R.
J. Chem. Soc., Chem. Commun., (21), 1176-7 (1972).

Effect of carbon sorption by a nickel catalyst on the kinetics of ortho-para hydrogen conversion.

Gaidai, N. A.; Dzagnidze, N. Sh.; Kiperman, S. L.
Kinet. Katal., 13(4), 954-60 (1972).

Nickel oxide silica catalyst for conversion of orthohydrogen to parahydrogen at low temperature.

Nishimura, Yusaka; Nakajima, Fumito.
Witachi Ltd., Japan, Kokai.
Pat. No. 74 41290 Date: 22/03/72.

Theoretical rates and correlation functions in ortho-para molecular hydrogen conversion on paramagnetic surfaces.

Ilisca, E.; Legrand, A. P.
Phys. Rev. B, [3]5(12), 4994-9 (1972).

E. Ilisca and A. P. Legrand, Phys. Rev. B 5, 499 (1972).

Orientation effect of the surface magnetization of ferromagnetic catalysts on ortho-para hydrogen conversion.

Ilisca, E.; Gallais, E.
Phys. Rev. B, 6(7), 2858-9 (1972).

Parahydrogen conversion and hydrogen-deuterium equilibration over carbon surfaces.

Ishikawa, Yuichi
155 pp. Avail. Univ. Microfilms, Ann Arbor, Mich., Order No. 72-9478
From: Diss. Abstr. Int. B 1972, 32(9), 5296.

Conversion process for orthohydrogen and parahydrogen.

Kawazura, Hiroshi; Ohmori, Toshio; Yamamoto, Yoshiro; Kobayashi, Tsutomu;
Koriya, Yoshinobu.
Japan Synthetic Rubber Co., Ltd.
Pat. No. 74 81293 Date: 12/12/72.

Alkali metal insertion compound.

Kawazura, Hiroshi; Umori, Toshio; Yamamoto, Yoshiro; Kobayashi, Tsutomu;
Kariya, Yoshinobu.
Japan Synthetic Rubber Co., Ltd.
Japan, Kokai.
Pat. No. 74 82799 Date: 12/12/72

1972 Cont'd:

Reactions in the rare earth metal-hydrogen system at increased temperatures and atmospheric pressure.

Konenko, I. R.; Gaifutdinova, R. K.; Gorshkova, L. S.; Tolstopyatova, A. A.; Berg, L. G.

Conference; Fiz. Khim. Gidridov; (72) p 112-22; in Russ.

Reactions in the rare earth metal-hydrogen system at increased temperatures and atmospheric pressure.

Konenko, I. R.; Gaifutdinova, R. K.; Gorshkova, L. S.; Tolstopyatova, A. A.; Berg, L. G.

Fiz. Khim. Gidridov, 112-22. Akad. Nauk Ukr. SSR, Inst. Probl. Materialoved: Kiev, USSR (1972).

Catalytical activity of rare earth metals and their hydrates in the para-ortho-hydrogen conversion reaction.

Konenko, I. R.; Gaifutdinova, R. K.; Gorshkova, L. S.; Tolstopyatova, A. A.; Moreva, N. I.

Zh. Fiz. Khim., 46(8), 2167 (1972).

Moeller, T., "Comprehensive Inorganic Chemistry" (Bailar, Emeleus, Nyholm, and Trotman-Dickenson, Eds.), Vol. 4, p. 3. Pergamon, Oxford, 1972.

Novel radical salts polymer catalyst carrying enhanced para-ortho-hydrogen conversion.

Murano, Kentaro; Kawazura, Hiroshi; Inokuchi, Hiroo; Ohmori, Toshio.

Bull. Chem. Soc. Jap., (72) p 3230; Vol. 45; No. 10; in Eng.

Para-hydrogen conversion on ion-exchanged polystyrene sulfonate.

Tezuka, Yoshisato; Kanesaka, Isao; Toyooka, Keiko; Takeuchi, Toyosaburo.

Z. Phys. Chem. (Frankfurt am Main), 80(3-4), 210-219 (1972).

Catalytic activity and selectivity of low-temperature adsorption in the series of ortho-para modifications of hydrogen on synthetic zeolites.

Zhun, G. G.; Slagol, Yu. P.

Tr. Fiz.-Tekh. Inst. Nizk. Temp., Akad. Nauk Ukr. SSR, No. 15, 109-13.

From: Ref. Zh., Khim. 1972, Abstr. No. 188975.

Parahydrogen conversion over chromia gel near the Neel point.

Arias, J. A.; Selwood, P. W.
J. Catal., 30(2), 255-9 (1973).

Parahydrogen conversion and magnetocatalytic effects over yttria and lutetia.

Baron, Kenneth; Selwood, P. W.
J. Catal., 28(3), 422-7 (1973).

Use of diffusion models in porous catalysts.

Balfanz, F.; Gelbin, D.
Inzh.-Fiz. Zh., 25(4), 708-19 (1973).

Parahydrogen conversion of X1 zeolites.

Brown, D. E.; Eley, D. D.; Rudham, R.
J. Catal., 29(2), 246-52 (1973).

Comparison of some models of porous media for catalytic para-hydrogen-ortho-hydrogen conversion.

Dvorak, L.; Schneider, P.
Conference; Pore Struct. Prop. Mater., Proc. Int. Symp. RILEM/IUPAC; (73) p A107-A122; Vol. Part 1; in Eng.

Catalytic function of hydrogen bound to the surfaces of oxides.

Hall, W. Keith.
Acc. Chem. Res.; (75) p 257-63; Vol. 8; No. 8; in Eng.

Catalytic activity of organic semiconductors. Hydrogen conversion on triphenylene-alkali metal ion radical salts.

Kimura, Keisaku; Inokuchi, Hiroo.
J. Catal.; (73) p 49-59; Vol. 29; No. 1; in Eng.

Characterization of adsorbed intermediates on zinc oxide by infrared.

Kokes, R. J.
Accounts. Chem. Res., 6(7), 226-33 (1973).

Rare earth metals as catalysts in the para-ortho conversion of hydrogen.

Konenko, I. R.; Gaifutdinova, R. K.; Gorshkova, L. S.; Tolstopyatova, A. A.; Berg, L. G.; Moreva, N. I.
Kinet. Katal.; (73) p 203-9; Vol. 14; No. 1; in Russ.

Use of rare earth metals and their hydrides as catalysts of the para-ortho conversion of hydrogen.

Konenko, I. R.; Gaifutdinova, R. K.; Gorshkova, L. S.; Tolstopyatova, A. A.; Moreva, N. I.
Redkozemel. Metal., Splavy Soedin., Mater. Soveshch., 7th, Meeting Date 1972, 319-20. Edited by: Savitskii, E. M. "Nauka": Moscow, USSR (1973).

Regularities in a change in the catalytic activity of rare earth metal hydrides in the high-temperature para-ortho conversion of hydrogen.

Konenko, I.R.; Gaifutdinova, R.K.; Gorshkova, L.S.; Tolstopyatova, A.A.; Berg, L.G.; Moreva, N.I.
Kinet. Katal. 14(2), 426-31 (1973).

1973 Cont'd:

Rare earth metals as catalysts in the para-ortho conversion of hydrogen.

Konenko, I. R.; Gaifutdinova, R. K.; Gorshkova, L. S.; Tolstopyatova, A. A.; Berg, L. G.; Moreva, N. I.
Kinet. Katal., 14(1), 203-9 (1973).

Use of rare earth metals and their hydrides as catalysts of the para-ortho conversion of hydrogen.

Konenko, I. R.; Gaifutdinova, R. K.; Gorshkova, L. S.; Tolstopyatova, A. A.; Moreva, N. I.
Document type: conference; Redkozemel. Metal., Spalvy Soedin., Mater. Soveshch., 7th; (73) p 319-320; in Russ.

Spin waves in magnetocatalytic phenomena.

Levy, J. C.; Gallais, E.
Tr. Mezhdunar. Konf. Magn., Meeting Date 1973, Volume 3, 132-4, "Nauka": Moscow, USSR (1973).

Catalyst for ortho- and para-hydrogen conversion.

Nishimura, Yusaku; Nakajima, Fumito
Hitachi, Ltd.
Japan. Kokai JP 48/59090 [73/59090], 18 Aug 1973, 3 pp.

Para to ortho-hydrogen conversion on magnetic surfaces.

Petzinger, K. G.; Scalapino, D. J.
Phys. Rev. B; (73) p 266-79; Vol. 8; No. 1; in Eng.

Selwood, P. W., J. Catal., 28, 422 (1973).

Ortho-para conversion and isotopic exchange of hydrogen on uranium and various uranium compounds.

Tanabe, Tetsuo; Adachi, Hirohiko; Imoto, Shosuke.
Technol. Rep. Osaka Univ., 23(1121-1154), 721-6 (1973).

Kinetic studies on hydrogenase. Parahydrogen-orthohydrogen conversion and hydrogen-deuterium exchange reactions.

Yagi, Tatsuhiko; Tsuda, Motoyuki; Inokuchi, Hiroo.
J. Biochem. (Tokyo), 73(5), 1069-81 (1973).

Homomolecular hydrogen exchange on rare earth metal films.

Zhavoronkova, K. N.; Korabel'nikova, L. M.
Kinet. Katal., 14(4), 966-9 (1973).

Catalytic activity of a NaX-type zeolite in an ortho-para conversion reaction.

Zhun, G. G.; Blagoi, Yu. P.
Zh. Fiz. Khim., 47(1), 154-7 (1973).

Catalyzed [ortho-parahydrogen] conversion and magnetocatalytic effects on europium monoxide and chromium dioxide.

Arias, J. A.; Selwood, P. W.
J. Catal., 35(2), 273-7 (1974).

Activation of yttria, lutetia, and ytterbia for the ortho-parahydrogen conversion.

Arias, J. A.; Selwood, P. W.
J. Catal.; (74) p 284-8; Vol. 33; No. 2; in Eng.

Ortho-para hydrogen conversion in paramagnetic solutions.

Atkins, P. W.; Clugston, M. J.
Mol. Phys., 27(6), 1619-31 (1974).

Parahydrogen conversion by organic monoradicals.

Brauer, H. D.; Schmidt, R.; Sartorius, R.
Z. Phys. Chem. (Frankfurt am Main), 89(5-6), 225-9 (1974).

Catalytic activity and annealing behavior of two austenitic alloys of different stacking fault energy.

Carrion, J.; Criado, J. M.; Gonzalez, F.; Herrera, E. J.; Trillo, J. M.
Electron. Fis. Apl., 17(1-2), 221-5 (1974).

Conversion of parahydrogen to orthohydrogen in a gamma-ray and neutron radiation field.

Conant, J. W.; Edeskuty, F. J.; Huston, J. E.; Thome, F. V.
Report, LA-5436-MS, 8 pp. Avail. Dept. NTIS
From: Nucl. Sci. Abstr. 1974, 29(6), 12561.

Conversion of o-hydrogen to p-hydrogen by neutron scattering in solid o-hydrogen.

Diehl, H. W.; Biem, W.
Report, AED-CONF-74-089-008, 6 pp. Avail. INIS
From: Nucl. Sci. Abstr. 1974, 30(10), 27538.

Para-hydrogen molecules in solid ortho-hydrogen.

Diehl, H. W.
Z. Phys., 271(3), 235-43 (1974).

Parahydrogen conversion on neodymium and dysprosium oxides.

Eley, D. D.; Forrest, H.; Rudham, R.
J. Catal., 34(1), 35-40 (1974).

Ortho hydrogen-para hydrogen interconversion catalysts.

Inoguchi, Hiroo; Murano, Kentaro; Kawazura, Hiroshi; Kobayashi, Tsutomu.
Japan Synthetic Rubber Co., Ltd., Japan, Kokai.
Pat. No. 75 115690 Date: 26/02/74.

Kay N., Fluid mechanics and heat transfer. Cambridge University Press, 3rd Ed. (1974).

1974 Cont'd:

Conversion process for orthohydrogen and parahydrogen.

Kawazura, Hiroshi; Ohmori, Toshio; Yamamoto, Yoshiro; Kobayashi, Tsutomu;
Koriya, Yoshinobu;
Japan Synthetic Rubber Co., Ltd., Japan, Kokai.
JP 49/81293 [74/81293], 6 Aug 1974, 5 pp.

Natural ortho-para conversion in hydrogen and deuterium in liquid and solid states.

Milenko, Yu. Ya.; Sibileva, R. M.
Ukr. Fiz. Zh. (Russ. Ed.), 19(12), 2008-14 (1974).

Nickel oxide silica catalyst for conversion of orthohydrogen to parahydrogen at low temperature.

Nishimura, Yusaku; Nakajima, Fumito.
Hitachi, Ltd.
Japan, Kokai JP 49/41290 [74/41290], 18 Apr 1974, 5 pp.

Comparison of the catalytic activities of metal oxides for hydrogen-deuterium equilibration and ortho-parahydrogen conversion.

Otsuka, Kiyoshi; Keii, Tominaga.
Bull Chem. Soc. Jap.; (74) p 234-5; Vol. 47; No. 1; in Eng.

Ortho-para conversion of hydrogen on zeolite and metal-zeolite catalysts.

Paranosenkov, V.P.; Gryaznova, Z.V.; Tsitsishvili, G.V.; Krupennikova, A. Yu.; Ponomareva, N.N.
Dokl. Akad. Nauk SSSR; (74) 0 1125-6 (Phys. Chem.); Vol. 217; No. 5; in Russ.

Theory of catalytic conversion of parahydrogen by organic radicals.

Reinsch, Ernst A.
Mol. Phys., 28(3), 683-94 (1974).

Para to ortho hydrogen conversion on gadolinium, yttrium, gadolinium trioxide and yttrium trioxide.

Rossington, D. R.; Capozzi, V. F.
J. Am. Ceram. Soc., 57(11), 474-7 (1974).

Para- to ortho-hydrogen conversion on nonmetallic magnetic surfaces.

Scalapino, D. J.; Petzinger, K. G.
AIP (Amer. Inst. Phys.) Conf. Proc.; (74) p 8-18; Vol. 18, Pt. 1; in Eng.

Diffusion and ortho-para conversion in solid hydrogen.

Schmidt, F.
Phys. Rev. B, 10(10), 4480-4 (1974).

Ferric hydroxide as a catalyst for ortho-para conversion of hydrogen.

Seifert, Peter; Deutschmann, Ludmila; Sur, Lothar.
Exp. Tech. Phys.; (74) p 355-60; Vol. 22; No. 4; in Ger.

Ross, P. N., Jr., and Delgass, W. N.; J. Catal. 33, 219 (1974).

Journal of Catalysis 33, 284-288 (1974).

1974 Cont'd:

Relations between adsorption and catalysis in the carbon monoxide oxidation and the para-hydrogen conversion on platinum.

Voelter, Joachim.

Z. Chem.; (74) p 180-6; Vol. 14; No. 5; in Ger.

Catalytic efficiency of pure and carbon monoxide-poisoned platinum in the parahydrogen conversion.

Voelter, J.; Herman, M.

Z. Anorg. Allg. Chem., 405(3), 315-28 (1974).

Theory of ortho-para conversion in solid hydrogen at high densities.

Berlinsky, A. John.

Phys. Rev. B, 12(4), 1482-6 (1975).

Conversion of para to orthohydrogen in a gamma-ray and neutron radiation field.

Conant, J. W.; Edeskuty, F. J.; Huston, J. E.; Thome, F. W.

Cryogenics, 15(1), 12-16 (1975).

Hydrogen activation on zinc oxide.

Conner, W. C., Jr.; Kokes, R. J.

J. Catal., 36(2), 199-210 (1975).

Phonon- and libron-excitation with ortho-para conversions by neutron scattering on solid hydrogen.

Diehl, H. W.; Biem, W.

Z. Phys. B, 20(2), 137-46 (1975).

Parahydrogen in solid orthohydrogen. General theory and applications to the ortho-para conversion by neutron scattering.

Diehl, H. W.; Biem, W.

Fiz. Nizk. Temp. (Kiev). 1(6), 789-95 (1975).

Surface reactivity of nickel and nickel hydride films as catalysts in parahydrogen conversion.

Frackiewicz, A.; Poleski, M.; Palczewska, W.

J. Catal., 40(2), 184-9 (1975).

Catalytic function of hydrogen bound to the surfaces of oxides.

Hall, W. Keith

Acc. Chem. Res., 8(8), 257-63 (1975).

Effect of an external magnetic field on the rate of the catalytic ortho-para conversion of hydrogen.

Gołovin, A. V.; Buyanov, R. A.

Kinet. Katal., 16(1), 121-5 (1975).

Ortho hydrogen-para hydrogen interconversion catalysts.

Inoguchi, Hiroo; Murano, Kentaro; Kawazura, Hiroshi; Kobayashi, Tsutomu.

Japan Synthetic Rubber Co., Ltd., Japan, Kokai.

JP 50/115690 [75/115690], 10 Sept 1975, 6 pp.

Ortho-/parahydrogen conversion and hydrogen-deuterium equilibration over carbon surfaces.

Ishikawa, Yuichi; Austin, L. G.; Brown, D. E.; Walker, Philip L., Jr.

Chem. Phys. Carbon, 12, 39-108 (1975).

Conversion catalyst for ortho- and para-hydrogen.

Kawabata, Akira; Goto, Masatoshi; Ito, Takeshi.

Sakai Chemical Industry Co. Ltd.

Japan, Kokai.

Pat No. 76 83891 Date: 20/01/75.

1975 Cont'd:

Catalyst for ortho-para hydrogen conversion.

Kawabata, Akira; Goto, Masatoshi; Ito, Takeshi.
Sakai Chemical Industry Co. Ltd.; Osaka Oxygen Industries Ltd.
Japan, Kokai.
Pat. No. 77 17383 Date: 31/07/75.

Catalysts for ortho-para hydrogen conversion.

Kawabata, Akira; Goto, Masatoshi; Ito, Takeshi.
Sakai Chemical Industry Co. Ltd.; Osaka Oxygen Industries Ltd.
Japan, Kokai.
Pat. No. 77 17382 Date: 31/07/75.

Natural ortho-para conversion in solid hydrogen and deuterium.

Milenko, Ya. Yu; Sibileva, R. M.
Fiz. Nizk. Temp. (Kiev), 1(6), 796-8 (1975).

Low temperature parahydrogen enrichment catalyzed by paramagnetic ions supported on rutile.

Rudham, Robert; Tullett, Arthur D.
J. Chem. Soc., Faraday Trans. 1, 71(12), 2361-5 (1975).

Low-temperature parahydrogen conversion on X-zeolite containing paramagnetic cations.

Rudham, R.; Tullett, A. D.; Wagstaff, K. P.
J. Catal., 38(1-3), 488-90 (1975).

Measurement of the rate of ortho-para conversion in liquid hydrogen in contact with nickel-alumina catalyst by nuclear magnetic resonance. Effect of molecular diffusion.

Tourneur, Jacky; Legrand, Andre-Pierre; Marchand, Daniel.
C. R. Hebd. Seances Acad. Sci., Ser. C, 281(21), 841-4 (1975).

Effect of iron (III) oxide on the selectivity of zeolite caA during the low-temperature adsorption of a mixture of molecular hydrogen-molecular deuterium with hydrogen-molecular deuterium isotopes.

Yakovlev, V. A.; Parbuzin, V. S.
Khim. Fak. Mosk. Gos. Univ. im. Lomonosova, Moscow.
Technical report; Deposited Doc.; (75) p 4 pp.; No. VINITI 809-75; in Russ.

Dvorak, L. and Schneider, P.; Comparison of some models of porous media in the catalytic para-/ortho-hydrogen conversion. J. Cat. 42 408 (1976).

Changes in the catalytic activity of a nickel powder caused by milling.

Carrion, J.; Criado, J. M.; Gonzalez, F.; Herrera, E. J.

Rev. Port. Quim., 18(1-4), 93-6 (1976).

Zinc oxide and chromia as catalysts for the isomerization of butene, the hydrogenation of ethylene, and the isotopic exchange and allotropic conversion of hydrogen.

Conner, William, C., Jr.

Diss. Abstr. Inst. B 1976, 36(11), 5603-4.

Ortho-parahydrogen conversion by oxygen adsorbed on graphite.

Dericbourg, Jacques

C. R. Hebd. Seances Acad. Sci. Ser. C, 282(11), 491-3 (1976).

Study of the adsorbed-phase conversion of ortho- to para-hydrogen. Case of nitric oxide, comparison with oxygen.

Dericbourg, Jacques

C. R. Hebd. Seances Acad. Sci. Ser. C, 283(12), 519-20 (1976).

Fukushima, T., and Ozaki, A., J. Catal. 41, 82 (1976).

Conversion catalyst for ortho- and para-hydrogen.

Kawabata, Akira; Goto, Masatoshi; Ito, Takeshi.

Sakai Chemical Industry Co., Ltd., Japan.

Japan, Kokai JP 51/83891 [76/83891], 22 Jul 1976, 6 pp.

Study of the para-ortho-conversion kinetics of hydrogen on carbides of Group IV and VB metals.

Kharlamov, A. I.; Rafal, A. N.

Dopov. Akad. Nauk Ukr, RSR, Ser. B; Geol., Khim. Biol. Nauki, (11), 1009-12 (1976).

Collinear reactive scattering atomic hydrogen on molecular hydrogen in the Magnus approximation.

Knapp, E. W.; Krueger, H.

Kaiserslautern, Ger.

Chem. Phys., 18(3-4), 375-83 (1976).

Extrinsic field effect and absolute para-hydrogen conversion rate on lutetia.

Madhusudhan, C. P.; Selwood, P. W.

J. Catal., 45(1), 106-9 (1976).

Magnetic effects on the ortho-parahydrogen conversion over alpha-chromium (III) oxide, cobalt (II) oxide, and manganese (II) oxide.

Ng, C. F.; Selwood, P. W.

J. Catal.; (76) p 252-9; Vol. 43; No. 1-3; in Eng.

1976 Cont'd:

Catalytic activity of tantalum hydride in parahydrogen conversion.

Poleski, M.; Frackiewicz, A.; Palczewska, W.

React. Kinet. Catal. Lett., 4(2), 199-205 (1976).

Interpretation of ortho-para hydrogen conversion.

Truhlar, Donald G.

J. Chem. Phys., 65(3), 1008-10 (1976).

Thermometric fixed points of hydrogen.

Ancsin, J.

Metrologia; (77) p 79-86; Vol. 13; No. 2; in Eng.

Neutron scattering in solid hydrogen.

Bickerman, A.; Spitzer, H.; Stiller, H.; Lechner, R. E.; Scherm, R.; Volino, F.; Meyer, H.

Proc. Int. Conf. Lattice Dyn., Meeting Date 1977, 482-4. Edited by: Balkanski, M. Flammarion Med.-Sci.: Paris, Fr.

Magnetic excitations on atomically rough surfaces.

Bohnen, K. P.; Pink, D. A.

Physica B + C (Amsterdam), 86-88B+C, Pt. 3, 1391-2 (1977).

Catalysts for ortho-para hydrogen conversion.

Kawabata, Akira; Goto, Masatoshi; Ito, Takeshi

Sakai Chemical Industry Co., Ltd.; Osaka Oxygen Industries, Ltd., Japan
Japan, Kokai JP 52/17382 [77/17382], 9 Feb 1977, 4 pp.

Catalytic activity of hafnium, tantalum, and tungsten carbides in the high-temperature para-ortho conversion of hydrogen.

Kharlamov, A. I.; Rafal, A. N.; Samsonov, G. V.; Belov, A. S.

Teor. Eksp. Khim.; (77) p 119-22; Vol. 13; No. 1; in Russ.

Catalytic activity of hafnium, tantalum, and tungsten carbides in the high-temperature para-ortho conversion of hydrogen.

Kharlamov, A. I.; Rafal, A. N.; Samsonov, G. V.; Belov, A. S.

Teor. Eksp. Khim., 13(1), 119-22 (1977).

Hydrogenation of propylene in the presence of rare earth metal hydrides.

Konenko, I. R.; Gorshkova, L. S.; Klabunovskii, E. I.; Moreva, N. I.

Kinet. Katal., 18(5), 1301-4 (1977).

The ortho-para forms of hydrogen, deuterium, and tritium: radiation and self-induced conversion kinetics and equilibria.

Pyper, J. W.; Briggs, C. K.

Lawrence Livermore Lab., [Rep.] UCRL, UCRL-52278, 20 pp. (1977).

Magnetic field effects on the catalyzed nondissociative parahydrogen conversion rate.

Selwood, P. W.

J. Catal.; (77) p 15-23; Vol.50; No. 1; in Eng.

Nuclear magnetism of solid hydrogen at reduced ortho concentration.

Vinegar, H. J.; Byleckie, J. J.; Pound, R. V.

Phys. Rev. B, 16(7), 3016-23 (1977).

The libron spectra and conversion as a function of ortho-para concentration in solid hydrogen and deuterium.

Berkhout, Piet J.; Minneboo, J. T.; Silvera, Isaac F.
J. Low Temp. Phys., 32(3/4), 401-17 (1978).

Introduction to a theory of ortho-para hydrogen conversion on paramagnetic catalysts: the magnetic field effect.

Ilisca, E.
Phys. Rev. Lett., 40(23), 1535-8 (1978).

Catalytic activity of borides in hydrogen conversion and the charge state of the elements in them.

Kharlamov, A. I.; Aleshin, V. G.
Dopov. Akad. Nauk Ukr. RSR, Ser. B: Geol., Khim. Biol. Nauki, (2), 146-9 (1978).

Catalytic activity and x-ray electronic spectra of iron and nickel borides.

Nemoshkalenko, V. V.; Kharlamov, A. I.; Serebryakova, T. I.; Aleshin, V. G.
Kinet. Katal., 19(6), 1567-72 (1978).

Equilibration of ortho-para hydrogen using chromium potassium sulfate for use in vapor pressure thermometry.

Sakurai, Hirohisa
Jpn. J. Appl. Phys., 17(6), 1141-2 (1978).

The effect of a magnetic field on the catalyzed nondissociative parahydrogen conversion rate.

Selwood, P. W.
Adv. Catal.; p 23-57; Vol. 27; in Eng. (1978).

Specific catalytic activity of scandium films in reference to ortho-para conversion and isotope exchange in molecular hydrogen.

Zhavoronkova, K. N.; Peshkov, A. V.; Spivak, N. A.
Tr. - Mosk. Khim.-Tekhnol. Inst. im. D. I. Mendeleeva, 99, 89-92 (1978).

Ortho-para conversion of hydrogen on rare earth metal films.

Zhavoronkova, K. N.; Peshkov, A. V.
Tr. - Mosk. Khim.-Tekhnol. Inst. im. D. I. Mendeleeva, 99, 93-6 (1978).

Magnetically-catalyzed ortho-para hydrogen conversion on cobalt(II) exchanged A-type zeolites.

Jablonski, Janusz Mieczyslaw
Pol. J. Chem., 53(5), 1103-10 (1979).

Low-temperature ortho-para hydrogen conversion on A-type zeolites.

Jablonski, Janusz M.
Geterog. Katal., 4th, Pt. 2, 379-84 (1979).

Hydrogen conversion on metal-like and covalent nitrides.

Kharlamov, A. I.
Teor. Eksp. Khim.; (79) p 468-71; Vol. 15; No. 4; in Russ.

Hydrogen conversion on metal-like and covalent nitrides.

Kharlamov, A. I.
Teor. Eksp. Khim., 15(4), 468-71 (1979).

Regularities in a change in the catalytic activity of rare earth metal hydrided in the high-temperature para-ortho conversion of hydrogen.

Konenko, I. R.; Gaifutdinova, R. K.; Gorshkova, L. S.; Tolstoplyatova, A. A.;
Berg, L. G.; Moreva, N. I.
CHEMABS. journal 79070627

Thermally-induced ortho-para conversion anomaly in solid hydrogen under pressure.

Krause, John K.; Swenson, C. A.
Solid State Commun., 31(11), 833-6 (1979).

Hydrogenase activity in the dry state. Isotope exchange and reversible oxidoreduction of cytochrome c₃.

Kimura, Keisaku; Suzuki, Akira; Inokuchi, Hiroo; Yagi, Tatsuhiko
Biochim. Biophys. Acta, 567(1), 96-105 (1979).

LMSC-D085818. CLIR Cooler Components Definition Study (Nov. 30, 1979).

Simultaneous reaction gas chromatography with a reversible first order reaction. II.

Cremer, Erika; Kramer, Reinhard
J. Chromatogr., 107(2), 253-63 (1979).

Ortho-parahydrogen conversion on carbon.

Dericbourg, Jacques; Duval, Xavier.
C. R. Acad. Sci., Ser. C; (79) p 1484-6; Vol. 271; No. 25; in Fr.

Reliable ab initio calculation of a chemical reaction rate and a kinetic isotope effect: $H + H_2$ and $^2H + ^2H_2$.

Garrett, Bruce C.; Truhlar, Donald G.
Proc. Natl. Acad. Sci. U. S. A., 76(10), 4755-9 (1979).

Decrease in the rate of a heterogeneous catalytic process of hydrogen ortho-para conversion in a weak magnetic field.

Golovin, A. V.

Kinet. Katal.; (79) p 1061-4; Vol. 20; No. 4; in Russ.

Magnetically-catalyzed ortho-para hydrogen conversion on cobalt (II) exchanged A-type zeolites.

Jablonski, Janusz Mieczyslaw.

Pol. J. Chem.; (79) p 1103-10; Vol. 53; No. 5; in Eng.

Decrease in the rate of a heterogeneous catalytic process of hydrogen ortho-para conversion in a weak magnetic field.

Golovin, A. V.

Kinet. Katal.; 20(4), 1061-4 (1979).

Iodide synthesis and certain properties of titanium phosphides.

Muchnik, S. V.; Lynchak, K. A.; Chernogorenko, V. B.; Rafal, A.N.

Izv. Akad. Nauk SSSR, Neorg. Mater.; (79) p 605-7; Vol. 15; No. 4; in Russ.

Ortho para-hydrogen conversion on cobalt (II) oxide, manganese (II) oxide and some rare-earth oxides. A note on a recent theory of ortho para-hydrogen conversion on magnetic surfaces.

Ng, C. F.

Chem. Phys. Lett.; (79) p 187-91; Vol. 62; No. 1; in Eng.

Theory of ortho = parahydrogen conversion on paramagnetic and antiferromagnetic surfaces.

Ng, C. F.

Surf. Sci., 79(2), 740-88 (1979).

Ortho para-hydrogen conversion on cobalt (II) oxide, manganese (II) oxide and some rare-earth oxides. A note on a recent theory of ortho para-hydrogen conversion on magnetic surfaces.

Ng, C. F.

Chem. Phys. Lett., 62(1), 187-91 (1979).

Study of chromium carbides and complex carbides based on chromium, tungsten, and iron in the para-ortho conversion of hydrogen.

Rafal, A. N.; Kharlamov, A. I.; Lyudvinskaya, T. A.; Domasevich, L. T.

Katal. Konversiya Uglevodorodov, 4, 53-6 (1979).

Ortho-para hydrogen conversion on X and Y zeolites exchanged with cobalt (II), nickel (II) and copper (II) ions.

Wroclaw 50950, Pol.

Pol. J. Chem., 53(4), 871-9 (1979).

The ortho-para conversion of hydrogen on rare earth metal films.

Zhavoronkova, K. N.; Peshkov, A. V.

Geterog. Katal., 4th, Pt. 1, 397-402 (1979).

Ortho-para conversion of hydrogen on rare earth metal films.

Zhavoronkova, K. N.; Peshkov, A. V.

Dokl. Akad. Nauk SSSR, 246(6), 1395-9 [Phys. Chem.] (1979).

Hydrogen isotope equilibration on sodium films.

Chappell, M. J.; Eley, D. D.; Shooter, D.
J. Res. Inst. Catal., Hokkaido Univ., 28(3), 109-17 (1980).

Denn, M., Process Fluid Mechanics. Prentice Hall (1980).

Pressure transitions in solid molecular hydrogen below 0.5 K.

Haase, D. G.; Sears, J. O.; Orban, R. A.
Solid State Commun., 35(11), 891-4 (1980).

Quantum formulation of a magnetocatalytic reaction.

Ilisca, E.; Debauche, M.; Motchane, J. L.
Phys. Rev. B: Condens. Matter; (80) p 687-701; Vol. 22; No. 2, in Eng.

Nature of the catalytic action of metal-like compounds of d-metals.

Kharlamov, A. I.
Kinet. Katal.; (80) p 245-51; Vol. 21; No. 1; in Russ.

p-Hydrogen conversion on sulfide catalysts as a function of bond ionicity.

Kharlamov, A. I.
React. Kinet. Catal. Lett.; (80) p 339-44; Vol. 15; No. 3; in Eng.

p-Hydrogen conversion on sulfide catalysts as a function of bond ionicity.

Kharlamov, A. I.
React. Kinet. Catal. Lett.; 15(3), 339-44; (1980).

Behavior of nickel-copper alloy in hydrogenation, orthohydrogen-parahydrogen conversion and H₂-D₂ exchange reaction.

Khulbe, K. C.; Mann, R. S.; Manoogian, A.
Chem. Rev.; (80) p 417-28; Vol. 80; No. 5; in Eng.

Nast, T. C., Study of a Solid Hydrogen Cooler for Spacecraft Instruments and Sensors - Final Report, LMSC-D766177 (Aug. 1980).

Interpretation of a series of catalytic activities of metalloid compounds.

Il'chenko, N. I.

React. Kinet. Catal. Lett.; (82) p 327-32; Vol. 19; No. 3-4; in Russ.

The relationship of reaction rate to amounts adsorbed for the low-temperature ortho-para hydrogen shift.

Kauffman, David; Brown, Lee F.; Manogue, William H.

J. Catal., 71(2), 244-56 (1981).

Changes in the catalytic activity of metallic compounds in the para-ortho-conversion of hydrogen.

Kharlamov, A. I.; Rafal, A. N.

Katal. Katal.; (81) p 85-90; Vol. 19; in Russ.

Relation between the activity of d-metal borides in the reaction of hydrogen and the charge state of catalyst elements.

Kharlamov, A. I.

Kinet. Katal., 22(3), 684-9 (1981).

Catalytic activity of Group IV-VI d-metal sulfides in a hydrogen conversion reaction.

Kharlamov, A. I.; Rafal, A. N.; Drozdova, S. V.; Primachenko, V. F.

Ukr. Khim. Zh. (Russ. Ed.), 47(5), 542-3 (1981).

Activity of metal-like borides in the reaction of hydrogen para-ortho conversion.

Kharlamov, A. I.; Rafal, A. N.; Serebryakova, T. I.

Ukr. Khim. Zh. (Russ. Ed.); (81) p 1301-2; Vol. 47; No. 12; in Russ.

LMSC-DB11574. Upper Atmospheric Research Satellite Cryogenic Limb Array Etalon Spectrometer (CLAES) (July 1981).

Incoherent $J = 1 \rightarrow 0$ neutron scattering from solid hydrogen.

Myles, Charles W.; Ebner, C.

Phys. Rev. B: Condens. Matter, 23(9), 4741-8 (1981).

Cooling by conversion of para to ortho-hydrogen.

Sherman, Allen.

The USA as represented by the Administrator of the National Aeronautics and Space Administration.

US Pat. No. 4,392,039 Date: 10/09/81.

The self conversion of liquid ortho-hydrogen.

Stevenson, Richard

Indian J. Cryog., 6(4), 196-8 (1981).

Catalytic activity of films of samarium, copper and their compounds in homomolecular isotopic exchange and ortho-para hydrogen conversion reactions.

Boeva, D. A.; Zhavoronkova, K. N.; Byzova, E. V.

Ref. Zh., Khim. 1982, Abstr. No. 2181258.

Catalytic properties of samarium, copper, and samarium-copper films in homomolecular isotope exchange and ortho-para conversion of hydrogen.

Boeva, L. A.; Zhavoronkova, K. N.; Byzova, E. V.

USSR

Mekh. Katal. Reakts., Mater. Vses. Konf., 3rd, Vol. 1, 20-2.

Edited by: Borekov, G. K. (1982).

Molecular hydrogen in hydrogenated α -silicon.

Carlos, W. E.; Taylor, P. C.

Phys. Rev. B: Condens. Matter, 25(2), 1435-8 (1982).

Heat transfer Data Book, 1982 edition. General Electric Company.

Interpretation of a series of catalytic activities of metalloid compounds.

Il'chenko, N. I.

React. Kinet. Catal. Lett., 19(3-4), 327-32 (1982).

Catalytic activity of carbides of fourth period metals.

Kharlamov, A. I.; Rafal, A. N.; Domasevich, L. T.

Ref. Zh., Metall. 1982, Abstr. No. 3E93; in Russ.

Catalytic activity of d-metal carbides in the para-ortho conversion of hydrogen.

Kharlamov, A. I.; Rafal, A. N.; Domasevich, L. T.; Fedorus, V. V.

Tugoplav. Soedin., Kiev 105-12

From: Ref. Zh., Khim. (1982) Abstr. No. 281650.

Behavior of nickel-copper alloy in hydrogenation, orthohydrogen-parahydrogen conversion and H₂-D₂ exchange reaction.

Khulbe, K. C.; Mann, R. S.; Manoogian, A.

Chem. Rev., 80(5), 417-28 (1982).

Conversion of para and ortho hydrogen in the Jovian planets.

Massie, S. T.; Hunten, D. M.

Icarus, 49(2), 213-26 (1982).

Cooling by conversion of para- to ortho-hydrogen.

Sherman, Allan

United States National Aeronautics and Space Administration,

USA

U.S. Pat. Appl. US 301075 A0, 12 Mar 1982, 14 pp. Avail. NTIS Order No.

PAT-APPL-6-301 075.

Para-hydrogen conversion and hydrogen-deuterium equilibration catalyzed by diamagnetic iridium, platinum, and ruthenium complexes in nonaqueous solution.

Tadros, Maher E.; Vaska, Lauri

J. Colloid Interface Sci., 85(2), 389-40 (1982).

1982 Cont'd:

Numerical analysis of power conversion in an infrared para-hydrogen Raman laser
Uemura, Shohei; Tashiro, Hideo; Toyoda, Koichi; Namba, Susumu.
Reza Kagaku Kenkyu, 4, 111-16 (1982).

Role of the electronic factor in catalysis by titanium carbide and nitrides
in the conversion of hydrogen and oxidation of carbon monoxide.
Kharlamov, A. I.; Krivitskii, V. P.; Kindrat, M. M.
Kinet. Katal., 23(3), 654-61 (1982).

Low-temperature hydrogen-deuterium exchange and ortho-para conversion of
hydrogen on praseodymium, neodymium, samarium, lutetium, and hafnium films.
Zhavoronkova, K. N.; Boeva, O. A; Peshkov, A. V.; Fraifer, A. Yu; Byzova, E. V.
Kinet. Katal.; (82) p 881-8; Vol. 23; No. 4; in Russ.

Trapping of molecular hydrogen at surfaces via translational-rotational energy conversion.

Andersson, S.; Harris, J.

Phys. Rev. B: Condens. Matter, 27(1), 9-14 (1983).

Isotopic exchange and ortho-para conversion of hydrogen on films of samarium and its compounds with copper.

Boeva, O. A.; Zhavoronkova, K. N.; Byzova, E. V.

Kinet. Katal., 24(3), 629-32 (1983).

Hydrogen adsorption by alkali metal complexes of polycyclic aromatic hydrocarbon and graphite, and their solid state properties.

Enoki, Toshiaki; Sano, Mizuka; Inokuchi, Hiroo.

Mol. Cryst. Liq. Cryst. 96(1-4), 401-11 (1983).

Ortho-para conversion of hydrogen molecules on magnetic surfaces.

Ishi, Yasushi; Sugano, Satoru.

Surf. Sci., 127(1), 21-34 (1983).

Magnetocatalytic effect on rare earth oxides.

Jugel, J.; Schwab, G. M.; Voitlaender, J.

J. Chem. Phys., 78(7), 4755-62 (1983).

Catalytic activity of transition metal silicides in the para-ortho conversion of hydrogen.

Kharlamov, A. I.; Rafal, A. N.; Dvorina, L. A.

From: Ref. Zh. Khim. (1983) Abstr. No. 16B1260.

Para-ortho conversion of hydrogen on Group IV-VI transition metal nitrides.

Kharlamov, A. I.; Rafal, A. N.; Shvedova, L. K.; Kulik, O. P.

Tugoplavkie Nitridy, 62-5. Edited by: Kosolapova, Naukova Dumka: Kiev, USSR (1983).

Catalytic activity of transition metal silicides in the para-ortho conversion of oxygen.

Kharlamov, A. I.; Rafal, A. N.; Dvorina, L. A.

Zh., Khim. 1983, Abstr. No. 16B1260.

Investigation of a para-ortho hydrogen reactor for application to spacecraft sensor cooling, final report.

NAST, T. C. (1983).

Ortho-para conversion of hydrogen in copper as origin of time-dependent heat leaks.

Schwark, H.; Pobell, F.; Halperin, W. P.; Buchal, C.; Hanssen, J.; Kubota, M.; Mueller, R. M.

J. Low Temp. Phys., 53(5-6), 685-94 (1983).

1983 Cont'd:

A mechanism for the para-ortho conversion of hydrogen by diamagnetic substances.

Stevenson, Richard.

J. Catal.; (83) p 218-21; Vol. 79; No. 1; in Eng.

Stock, H. R. and Lowe A. Measurement and differential kinetic analysis of wall temperatures in monolith converters. Chem. Eng. Sci. 38 1039 (1983).

Isotope exchange and ortho-para conversion in molecular hydrogen on films of dysprosium-copper alloys.

Boeva, O. A.; Zhavoronkova, K. N.; Popova, N. N.; Gachinskaya, L. M.
Tr. Inst. - Mosk. Khim.-Tekhnol. Inst. im. D. I. Mendeleeva, 130, 109-19 (1984)

Coupled channel distorted wave method of atom-molecule reactive scattering: application to para to ortho hydrogen molecule conversion.

Choi, B. H.; Poe, R. T.; Tang, K. T.
J. Chem. Phys., 81(11), 4979-90 (1984).

Catalytical conversion from ortho-hydrogen to para-hydrogen.

Corat, E. J.
Report, CTA-IEAV-NT-002/84, 30 pp. Avail. INIS
From: INIS Atomindex 1985, 16(20), Abstr. No. 16:069242 (1984).

Ortho-para conversion of solid hydrogen as a function of density.

Driessen, A.; Van der Poll, E.; Silvera, Isaac F.
Phys. Rev. B: Condens. Matter, 30(5), 2517-26 (1984).

Dynamical aspects of ortho-para conversion on magnetic surfaces.

Ishii, Yasushi; Sugano, Satoru
J. Phys. Chem., 77(11), 2049-62 (1984).

Dependence of conversion rate in liquid hydrogen on ortho-para composition.

Milenko, Yu. Ya.; Sibilev, R. M.
Fiz. Nizk. Temp. (Kiev), 10(12), 1292-3 (1984).

Development of a para-orthohydrogen catalytic converter for a solid hydrogen cooler.

Nast, T. C.; Hsu, I. C.
Lockheed Palo Alto Res. Lab.
Adv. Cryog. Eng., 29, 723-31 (1984).

Rapp, R. A., "In situ studies of the high temperature oxidation of metals and alloys." Pure and App Chem 56 1715 (1984).

Low-temperature exothermic processes in solids, their physics, and their cryotechnical implication.

Schwark, M.
Ber. Kernforschungsanlage Juelich, Juel-1919, 60 pp. (1984).

Numerical calculation of Raman conversion by 4 wave mixing in para-hydrogen.

Tashiro, Hideo; Ohashi, Kazuhito; Aoki, Yoshitaka; Midorikawa, Katsumi;
Nagasaka, Keigo; Toyoda, Koichi; Namba, Susumu.
Reza Kagaku Kenkyu, 6, 192-4 (1984).

Direct experimental evidence for molecular hydrogen in amorphous hydrogenated silicon.

Von Loehneysen, H.; Schink, H. J.; Beyer, W.
Phys. Rev. Lett., 52(7), 549-52 (1984).

Wright, C. J. and Corbett, I. "Proposal in response to European Space Agency call for competitive offers." No A0/1-1627/84/NL/P13.

1985

Parametric study of two-frequency Raman conversion of 16 μ m region by four-wave mixing effect.

Bernardini, M.; Ferrario, A.; Giorgi, M.; Ribezzo, S.; Marchetti, S.; Palucci, A.

Nuovo Cimento Soc. Ital. Fis., D, 6D(6), 559-66 (1985).

Para-hydrogen conversion by solutions of sodium in liquid ammonia.

Bootle, Geraldine A.; Eley, Daniel D.; Rudham, Robert

Z. Phys. Chem. (Munich), 144, 47-57 (1985).

Butler, G., Bradshaw, T. W., Clark, N. S., Chadwick, A. T., Harris, G. H. C., Leach, P. and Price, D.; "Interim Progress Report on ESA contract number A0/1-1627/84/NL/PB, (1985).

PDMP 302.1.1 "Liquid Hydrogen Cycles, ", G. Kinard, draft November 1985.

"Air Liquefaction Technology. A Technical Review" by Astronautics for U.S. Air Force contract F33615-84-C-0100, December 1985.

Dynamical aspects in chemical reactions near solid surfaces - special reference to the ortho-para conversion on magnetic surfaces.

Ishii, Y.

Springer Ser. Solid-State Sci., 59(Dyn. Processes Ordering Solid Surf.), 13-19 (1985).

Low temperature heat release from copper: ortho-para conversion of hydrogen.

..., M.; Neganov, B. S.; Sahling, S.

J. Low Temp. Phys., 59(5-6), 547-59 (1985).

Relationship between the characteristics of the mechanism of ortho-para conversion of hydrogen on magnetic surfaces and macroscopic rate of the process.

Golovin, A. V.

Kinet. Katal., 27(3), 601-7 (1986).

Ishii, Y., "Theory of Nondissociative Ortho/Para Conversion in Magnetic Substances," in Progress in Surface Science, 21 (2), 163, (1986).

Ortho-para conversion in hydrogen bubbles in copper.

Kolac, M.; Neganov, B. S.; Sahling, A.; Sahling, S.

Jt. Inst. Nucl. Res.

Dubna, USSR

J. Low Temp. Phys., 63(5-6), 459-77 (1986).

Hydrogen Technology Conference NASA-Lewis, Para/Ortho Conversion presentations by J. White and G. Kinard (APCI), R. Farranto (Englehard), June 4-5, 1986.

1987

106: 178819u Study and manufacture of a para-/ortho-hydrogen catalytic converter for a space cryostat.

Baston, A. H.; Bradshaw, T. W.; Butler, G.; Clark, N.S.; Chadwick, A. T.; Harris, D.H.C., Leach, F.; Norris, J. O. W.; Price, D.

(Mater. Phys. Metall. Div. United Kingdom At. Energy Auth., Harwell, UK).

Report 1986, AERE-G-3774, HL86/923, ESA-CR(P)-2267, ETN-86-98142, 146 pp.

(Eng.). Avail. NTIS. From Sci. Tech. Aerosp. Rep. 1987, 25(5), Abstr. No. N87-14184.

UNCLASSIFIED

AIR PRODUCTS PARA/ORTHO CATALYST DISTRIBUTION LIST

AFSC/NAE (Dan Schaeffer) Wright-Patterson AFB OH 45433	1 Copy	ASD/XMRI (John Livingston) Wright-Patterson AFB OH 45433	1 Copy
AFSC/NAE (Mike Sneed) Wright-Patterson AFB OH 45433	1 Copy	General Dynamics Space Systems Division Attn: Mr Glen Yates Mail Stop: PI-9530 P.O. Box 85990 San Diego CA 92138	1 Copy
AFSC/NAE (Mike Mossee) Wright-Patterson AFB OH 45433	1 Copy		
WRDC/POPR (Lt Wade Smith) Wright-Patterson AFB OH 45433	1 Copy	Lockheed-California Company Attn: Mr Bruce J. Flornes Department 7232, Bldg 90-4, Plant A-2 P.O. Box 551 Burbank CA 91520	1 Copy
WRDC/POPR (Lourdes Maurice) Wright-Patterson AFB OH 45433	2 Copies		
WRDC/POPS (Charles Bauer) Wright-Patterson AFB OH 45433	1 Copy	McDonnell Douglas Attn: Mr Aubrey Bland 270B Mail Code: 2702421 P.O. Box 516 St Louis MO 63166	1 Copy
WRDC/POS (Benito Botteri) Wright-Patterson AFB OH 45433	1 Copy		
WRDC/POST (Lt Jeffrey Moler) Wright-Patterson AFB OH 45433	14 Copies	The Marquardt Company Engineering Attn: Mr Jerry Rosevear P.O. Box 9104 Van Nuys CA 91409	1 Copy
NASA-Lewis Research Center Attn: Mr Lawrence H. Fishbach Mail Stop: 6-12 21000 Brookpark Road Cleveland OH 44135	1 Copy	Rockwell International Rocketdyne Division Attn: Mr Leon Sraibinsky Department 631 6603 Canoga Avenue Canoga Park CA 91303	1 Copy
NASA-Lewis Research Center Attn: Mr Frank Humenik Mail Stop: 86-4 21000 Brookpark Road Cleveland OH 44135	1 Copy		
NASA-Lewis Research Center Attn: Mr John J. Reinmann Mail Stop: 86-7 21000 Brookpark Road Cleveland OH 44135	1 Copy	Rockwell International Rocketdyne Division Attn: Mr Phil Maddox Mail Stop: WB09 6633 Canoga Avenue Canoga Park CA 91303	1 Copy
NASA-Lewis Research Center Attn: Mr Gary Williamson Mail Stop: 2500-220 21000 Brookpark Road Cleveland OH 44135	6 Copies	Rockwell International Space Transportation Systems Division Attn: Mr William Bond Mail Stop: AD 38 12214 Lakewood Boulevard Downey CA 90241	1 Copy
NASA Langley Research Center Dr Jack Morris Mail Stop 352 Hampton VA 23665	1 Copy	Science Applications International Corp. (SAIC) Attn: Mr John V. Kleperis 1010 Woodman Drive, Suite 200 Dayton OH 45432	1 Copy
Center for Chemical Engineering National Bureau of Standards Attn: Mr O. R. Voth 325 Broadway Boulder CO 80303	1 Copy	Union Carbide Corporation Linde Division - R & D Dept. Attn: Mr Chris Gottsmann 61 East Park Drive P.O. Box 44 Tunnawanda NY 14151-0044	1 Copy
Aerojet TechSystems Company Advanced Systems Division Attn: Mr Charles J. O'Brian Dept 9910, Bldg 2001 P.O. Box 13222 Sacramento CA 95813	1 Copy	United Technologies Pratt & Whitney Attn: Mr Jerry Radecliffe P.O. Box 109600 West Palm Beach FL 33410-5600	1 Copy
Allied-Signal Aerospace Company AirResearch Manufacturing Attn: Mr Oscar Buchman Mail Stop: T-41 2525 West 190th Street Torrance CA 90509	1 Copy	United Technologies Pratt & Whitney Attn: Mr Carl Sypniewski P.O. Box 109600 West Palm Beach FL 33410-9600	1 Copy

UNCLASSIFIED

DL-1 *U.S. Government Printing Office: 1989 - 748-056/24152